# HANDBOOK OF INSTRUCTIONS

*for*

# MODEL 531

# CRYSTAL IMPEDANCE METER

(SIGNAL CORPS MODEL TS-683/TSM)

RADIO FREQUENCY LABORATORIES, INC.

BOONTON, NEW JERSEY

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**RADIO FREQUENCY LABORATORIES, INC.**

**BOONTON, NEW JERSEY**

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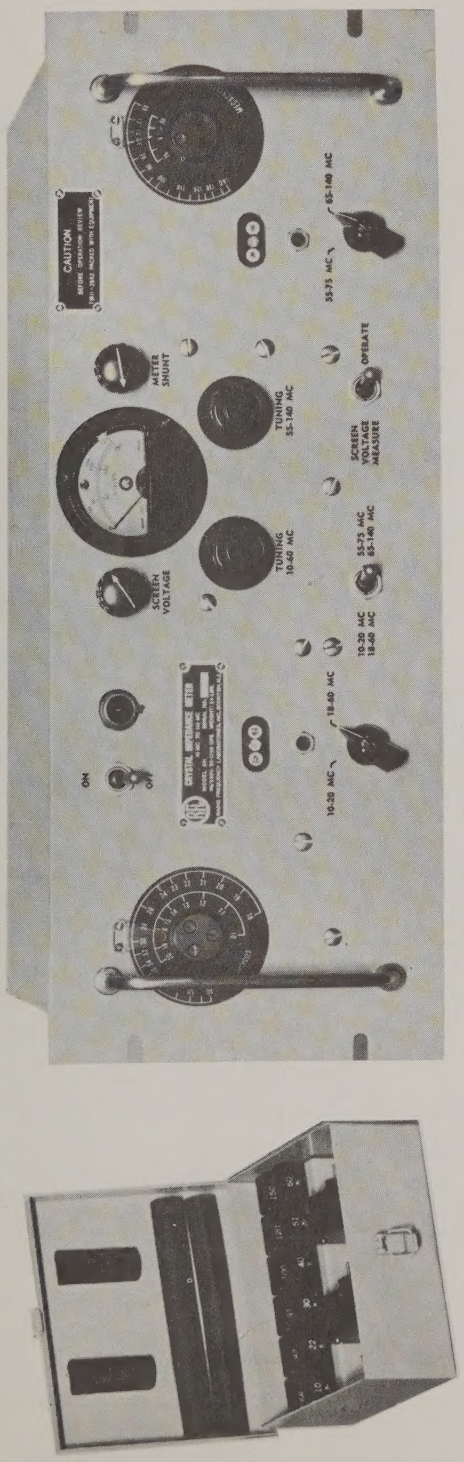



*Figure 1. Crystal Impedance Meter Model 531*

## SECTION I
## GENERAL DESCRIPTION

### 1. PURPOSE OF HANDBOOK.

The purpose of this handbook is to provide operating and servicing personnel with the necessary information concerning the installation, operation and maintenance of the Crystal Impedance Meter Model 531.

### 2. PURPOSE OF EQUIPMENT.

The Crystal Impedance Meter Model 531 is designed to measure directly the effective resonance and anti-resonance resistance of quartz crystal units in the frequency range of 10 to 140 megacycles.

### 3. GENERAL DESCRIPTION.

The C.I. Meter Model 531 is equivalent in all respects to the Signal Corps Crystal Impedance Meter TS-683/TSM.

The Crystal Impedance Meter Model 531 consists of two similar tuned-plate, tuned-grid variable-frequency oscillators and a power supply with a VR tube regulated plate voltage source. Each oscillator covers two of the specified bands, with switches to permit the use of either band, as desired. All circuits, except the VOLTAGE CHANGE-OVER switch, are switched and operated with front panel controls. In operation, the oscillator covering the frequency band of the crystal unit to be tested is selected by switches. Tuning knobs at the lower left and lower right of the microammeter permit adjustment of the corresponding left- or right-hand oscillator tuning dial to the crystal frequency. Crystal sockets are provided adjacent to the tuning dials. The microammeter, with an adjustable protective shunt, is used as a grid current indicator. Through a momentary contact switch, the unshunted microammeter may be connected with a series resistor to measure the screen grid potential of the oscillator tube in use.

The C.I. Meter operates from a power source of 115 or 230 volts ac (alternating current), 50 to 1,000 cps (cycles per second). A 5-foot, r-f (radio-frequency) output cable assembly with a plug attached, twelve calibrating resistors, a variable calibrating resistor, and an anti-resonance adapter are furnished with the meter.

The C.I. Meter is enclosed in a metal case designed for standard rack and panel mounting. The panel dimensions are 19 inches long by 7 inches high. The over-all depth, including handles and cable connectors, is 10-1/2 inches.

### 4. DESCRIPTION OF MINOR COMPONENTS.

a. Twelve plastic encased calibrating resistors, with pin connectors to match the spacing of the crystal sockets and having values of 10, 22, 30, 40, 51, 60, 68, 82, 91, 100, 120, and 150 ohms, are supplied with Crystal Impedance Meter Model 531.

*Figure 2. Calibrating Resistors and Adapters*

The resistors are substituted for the crystal unit during the course of resonance and anti-resonance resistance measurements.

b. A variable calibrating resistor, adapter VR-2, may also be used as a calibrating resistor below 50 megacycles. This adapter contains a 100-ohm composition rheostat and may be plugged into either of the two crystal sockets on the meter panel.

c. An anti-resonance adapter AR-1 is provided for insertion into either crystal socket on the meter panel. This adapter contains a similar socket to receive a crystal unit. When plugged into the adapter, the crystal unit is connected to the meter panel socket through an integral 32-uuf (micromicrofarad) load capacitor.

d. A small box is provided to hold the 12 calibrating resistors, the variable calibrating resistor, and the anti-resistance adapter.

e. A 5-foot r-f output cable assembly is supplied with the meter.

## 5. TECHNICAL CHARACTERISTICS.

The characteristics of Crystal Impedance Meter Model 531 are as follows:

| | |
|---|---|
| Frequency range | Four bands: 10 to 20 mc, 18 to 60 mc, 55 to 75 mc, 65 to 140 mc. |
| Resistance calibration | Twelve calibrating resistors with values of 10, 22, 30, 40, 51, 60, 68, 82, 91, 100, 120, and 150 ohms and a 100-ohm variable calibrating resistor are used. |
| Number of tubes | 4. |
| Oscillator | V1 (5654) |
| Oscillator | V2 (5654) |
| Rectifier | V3 (5Y3GT) |
| Voltage regulator | V4 (OA2) |
| Required power source | 115 v or 230 v ac, 50 to 1,000 cps, 30 w. |

## SECTION II
## INSTALLATION AND ADJUSTMENT

### 1. UNPACKING THE EQUIPMENT.

Cut the metal bands. Open the cartons that protect the equipment; or, if heavy wrapping has been used, remove it carefully and take out the components. Check the contents of the packing case against the master packing slip.

**CAUTION**

**BE CAREFUL IN UNPACKING AND HANDLING EQUIPMENT; IT IS EASILY DAMAGED. IF IT BECOMES DAMAGED OR EXPOSED, A COMPLETE OVERHAUL MIGHT BE REQUIRED OR EQUIPMENT MIGHT BE RENDERED USELESS.**

Note. Save the original packing cases and containers. They can be used again when the equipment is repacked for storage or shipment.

### 2. INSTALLATION OF EQUIPMENT.

The following steps should be followed in the installation of the equipment:

a. Check the contents of the packing case against the master packing list.

b. Thoroughly inspect the exterior of the C.I. Meter for possible damage in shipment.

c. Loosen the nine binding head screws on the sides and back of the unit and remove the metal dust cover. Also remove the bottom cover plate.

d. Make sure the vacuum tubes are not broken and that they are seated properly in their sockets. (Note that both oscillator tubes are located underneath the chassis.)

e. Inspect the wiring to make certain that the leads are securely fastened to points of contact.

f. Inspect the subassembly parts such as the terminal strips to make certain they are securely fastened in place.

g. Remove the cap from the fuseholder (figure 15) and see that the fuse (1-ampere) has been installed.

h. Replace dust cover and bottom cover plate.

CAUTION

THE CHASSIS OF THE CRYSTAL IMPEDANCE METER HAS BEEN MOISTUREPROOFED AND FUNGIPROOFED. DO NOT REMOVE ANY OF THE PROTECTIVE COATING.

## 3. CONTROLS AND INSTRUMENTS.

a. GENERAL. - Haphazard operation or improper setting of the controls can cause damage to electronic equipment. For this reason it is important to know the function of every control. The actual operation of the equipment is discussed in Section III of this book.

CAUTION

IT IS OF GREAT IMPORTANCE THAT THE LINE VOLTAGE CHANGE-OVER SWITCH S2 (FIG.15) ON THE REAR OF THE UNIT BE SET CORRECTLY AND LOCKED IN THE OPERATING VOLTAGE POSITION. SCREEN VOLTAGE CONTROL R17 SHOULD BE SET TO ITS LOWEST VALUE (EXTREME COUNTER-CLOCKWISE POSITION) BEFORE THE POWER ON-OFF SWITCH S1 IS TURNED TO THE ON POSITION.

b. CONTROLS AND THEIR FUNCTIONS. - The following table lists the controls and instruments on the equipment and indicates their functions. Refer to figure 3 for illustrative identification of these controls and instruments.

TABLE 2—1. CONTROLS AND THEIR FUNCTIONS

| CONTROL | FUNCTION |
|---|---|
| ON-OFF switch S1. | Switches power on and off when C.I. Meter is connected to power source. |
| 115 v or 230 v VOLTAGE CHANGE-OVER switch S2 (located on rear of chassis). | Connects power transformer primary windings for 115- or 230-volt operation. |
| 10-20 MC -- 18-60 MC switch S3. | Selects frequency band of low-frequency oscillator. |
| 55-75 MC -- 65-140 MC switch S4. | Selects frequency band of high-frequency oscillator. |

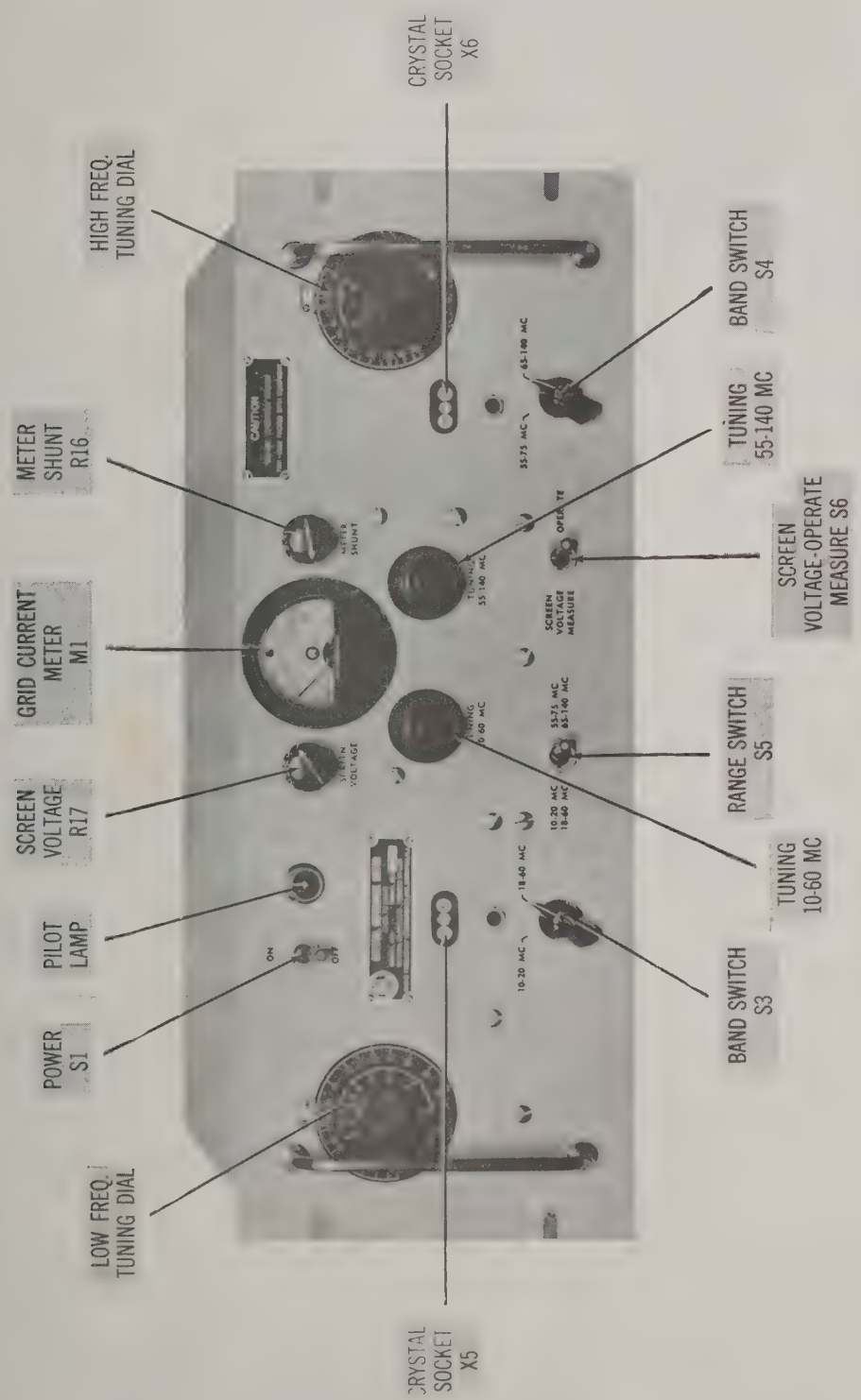



*Figure 3. Front Panel View of Crystal Impedance Meter Model 531*

TABLE 2—1. CONTROLS AND THEIR FUNCTIONS, (CONT'D)

| CONTROL | FUNCTION |
|---|---|
| 10-20 MC 55-75 MC -- 18-60 MC 65-140 MC switch S5. | Connects either high- or low-frequency oscillator into operating circuit. |
| SCREEN VOLTAGE MEASURE--OPERATE switch S6. | Connects meter M1 to read grid current in OPERATE position and to read screen voltage in SCREEN VOLTAGE MEASURE position. |
| Low-frequency tuning dial (10-60 MC). | Tunes low-frequency oscillator to desired frequency. Used in connection with switches S3 and S5. |
| High-frequency tuning dial (55-140 MC). | Tunes high-frequency oscillator to desired frequency. Used in connection with switches S4 and S5. |
| SCREEN VOLTAGE control R17. | Varies screen voltage of oscillator tubes and to adjust drive level. |
| METER SHUNT control R16. | Varies value of shunt resistor across grid current meter. |
| Grid current meter M1. | D-c microammeter used to measure a convenient proportion of total rectified grid current. It also is used as a d-c voltmeter (with external multiplying resistor) to measure screen voltage. |
| Crystal sockets X5 and X6. | Two-pin sockets with a center-to-center spacing of .486'' made to accept pins of .050'' in diameter. |
| Ground jacks J2 and J3. | Provide convenient ground connections below crystal sockets. |
| Light indicator (pilot lamp) I1. | Incandescent lamp, covered by lens, which lights when current is flowing through primary of transformer T1. |

TABLE 2--1. CONTROLS AND THEIR FUNCTIONS, (CONT'D)

| CONTROL | FUNCTION |
|---|---|
| R-f output jack J1. | A coaxial cable receptacle from which a small portion of the r-f output of the C.I. Meter may be connected (via r-f cable assembly W5) to frequency measuring equipment. |
| Fuseholder. | Holds 2-ampere fuse. |

## SECTION III

## OPERATION

### 1. STARTING PROCEDURE.

Perform the starting procedure given below before using the operating procedure described in paragraph 2. If any abnormal condition is observed during the starting procedure, throw the ON-OFF switch to the OFF position, disconnect the power cable, and refer to the equipment performance check list (para. 10e).

Note. All initial adjustments on the C.I. Meter are made at the factory; field adjustments should not be necessary. The capacitor in adapter AR-1 has been factory-adjusted to 32 uuf. This adjustment should not be altered.

a. Set METER SHUNT control fully clockwise.

b. Set SCREEN VOLTAGE control fully counter-clockwise.

c. Determine whether the power source is 115 volts or 230 volts, and set VOLTAGE CHANGE-OVER switch S2 (located on back of chassis) to the proper value. The proper setting for either source voltage is marked clearly on the chassis.

d. Insert the power cord into the a-c outlet.

### 2. OPERATING PROCEDURE.

a. MEASUREMENT OF RESONANCE RESISTANCE.

(1) Switch the ON-OFF switch to the ON position. Allow the C.I. Meter to warm up for 15 minutes. Set range switch S5 (figure 3) to the desired frequency range. If switch S5 is set to the low position, adjust rotary band switch S3 to the

specific range desired. If S5 has been set to the high position, use rotary band switch S4 to obtain the proper setting.

(2) Plug the crystal unit into the appropriate socket (crystal socket X5 for the low-frequency range or crystal socket X6 for the high-frequency range).

(3) Increase the screen grid voltage by turning the SCREEN VOLTAGE control slightly in a clockwise direction.

(4) Rotate the low-frequency tuning dial or the high-frequency tuning dial (depending on the desired frequency range) to obtain the maximum grid current meter reading, and adjust the SCREEN VOLTAGE control for a reading of 50 to 75 ua (microamperes).

(5) If no meter reading is obtained when the tuning dial is rocked back and forth through the crystal unit's nominal frequency, advance the SCREEN VOLTAGE control again and repeat steps (4) and (5).

(6) Select two calibrating resistors: one to give a slightly higher meter reading, the other to give a slightly lower meter reading than the value obtained from the crystal unit.

(7) From the two resistors selected, use the calibrating resistor that gives the meter reading closest to that of the crystal unit, and set the drive level in the following manner:

(a) Determine the correct drive level for the crystal unit under test according to information given in the specification covering the particular crystal unit.

(b) Express this drive level in terms of a voltage, E, across the calibrating resistor by means of the formula:

$$E = \sqrt{PR}$$

where:

P = drive level, in watts, and
R = resistance of calibrating resistor, in ohms.

example:

P = 4 mw = .004 watts, and
R = 40 ohms.

$$E = \sqrt{PR} = \sqrt{(.004)\ (40)} = \sqrt{.16}$$

E = .4 volts = voltage drop across R for drive level of 4 mw.

(c) Measure the voltage, E, in one of three ways outlined below.

1. Wrap 2 or 3 turns of #16 bare copper wire around each pin of the calibrating resistor. Insert the free end of each wire into the crystal socket on the panel. Keep the wire as short as possible; this will leave the calibrating resistor pins exposed for measurements. Measure the voltage from each pin to ground using a high-frequency voltmeter such as the General Radio Model 1800-A and its high-frequency probe. Obtain the voltage, E, by subtracting the smaller voltage reading from the larger reading.

2. To measure the voltage, E, for a large number of crystal units, use the Electronic Multimeter ME-56/TSM-3. Insert the probe of the meter into the crystal socket on the panel. Plug a calibrating resistor into the voltmeter probe and read the voltage drop, E, directly on the voltmeter dial.

3. A third method that may be used is to construct a crystal diode differential voltmeter (figure 4). Since this unit is frequency sensitive, calibrate the microammeter in volts, using the method described in paragraph 1. above, for each frequency at which it is used. This meter, if properly calibrated, can be used as a rapid and fairly accurate method of setting the voltage, E, across a calibrating resistor.

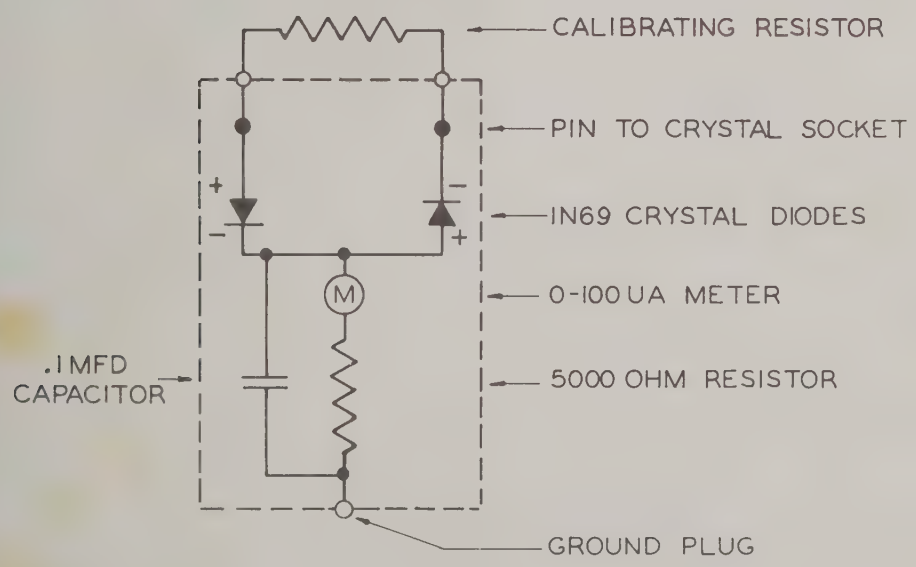



*Figure 4. Schematic Diagram of Differential Voltmeter*

(d) Vary the SCREEN VOLTAGE control and repeat the voltage measurements until the voltage drop is equal to that calculated in paragraph (b) above.

(e) The drive level now is adjusted properly for crystal units of this type and single selected frequency under test. This adjustment should remain constant throughout the remainder of the test. To reset this drive level for further measurements, read and record the screen voltage by holding the SCREEN VOLTAGE MEASURE--OPERATE switch in the SCREEN VOLTAGE MEASURE position, and by reading the voltage on the lower scale of the meter. The correct drive level then may be obtained for crystal units of the same type and frequency by resetting the screen voltage to the recorded value. It is advisable, however, to check this setting occasionally by repeating the adjustment procedure given in paragraphs (c) and (d) above.

(8) Remove the calibrating resistor and plug in the crystal unit. Rotate the tuning control to obtain maximum grid current meter reading. If the pointer goes off scale, adjust the METER SHUNT control for a convenient on-scale reading.

(9) Connect r-f cable assembly W2 between r-f output jack J1 and a radio receiver equipped with a bfo (beat-frequency oscillator); turn on the bfo. Obtain an approximate measurement of the crystal frequency by zero-beating the signal from the C.I. Meter with the signal of the bfo of the receiver. Read the frequency from the receiver tuning dial or the calibration chart (Section V).

(10) Replace the crystal unit with the calibrating resistor that gives the closest grid current reading, preferably on the low side, to the crystal unit. Rotate the tuning control of the C.I. Meter to obtain the same frequency as found in paragraph (9) above.

(11) Replace the crystal unit in its socket on the C.I. Meter and, if necessary, readjust the receiver tuning for zero-beat.

(12) Again substitute the calibrating resistor for the crystal unit. If the grid current meter reading is found to be greater than the reading for the crystal unit, select another calibrating resistor that gives the closest grid current reading, on the low side, to the crystal unit. Rotate the proper tuning control on the C.I. Meter until zero-beat is obtained again.

(13) Repeat the instructions given in paragraphs (11) and (12) above until the frequencies of the crystal unit and calibrating resistor are the same.

(14) Retain the crystal unit in the socket and adjust the METER SHUNT control for a convenient meter reading.

(15) Substitute a calibrating resistor in the crystal socket that will give a grid current reading just below, and another that will give a reading just above, that of the crystal unit.

(16) Note the values of the two calibrating resistors and the three grid

current meter readings and use the following method for calculating the effective resonance resistance, R, of the crystal unit.

$$R = R_l + \frac{(I_h - I_{xtal})(R_h - R_l)}{I_h - I_l}$$

where:

$R_h$ = higher calibration resistance value,
$R_l$ = lower calibration resistance value,
$I_h$ = higher grid current meter reading (using $R_l$),
$I_l$ = lower grid current meter reading (using $R_h$), and
$I_{xtal}$ = crystal unit grid current meter reading.

example:

$I_h$ = 128 ua
$I_{xtal}$ = 100 ua
$I_l$ = 73 ua
$R_h$ = 22 ohms
$R_l$ = 10 ohms

$$R = R_l + \frac{(I_h - I_{xtal})(R_h - R_l)}{I_h - I_l}$$

$$= 10 + \frac{(128 - 100)(22 - 10)}{(128 - 73)}$$

$$= 10 + \frac{(28)(12)}{55} = 10 + \frac{336}{55}$$

$$= 16.11 \text{ ohms.}$$

(17) A slightly more accurate method of measuring the resonance resistance is to use four calibrating resistors and obtain two readings below the crystal unit grid current meter reading; then plot the points on rectangular graph paper and read the effective resistance from the graph.

(18) When using the C.I. Meter below 50 mc, the variable calibrating resistor may be used for the operator's convenience. The C.I. Meter is operated in

the same manner as above by adjusting the proper controls until both frequency and grid current meter readings are the same. The resistance of the crystal unit may then be determined by measuring the resistance across the pins of the variable calibrating resistor.

(19) An accurate measurement of the operating frequency now can be made by connecting r-f cable assembly W2 to an appropriate frequency measuring instrument such as the following: Frequency Meter Set SCR-211, Frequency Meter TS-174/U, Frequency Measuring Assembly CY-93/FSM-1 (figure 10), or Frequency Calibrator-Meter Set AN/URM-18. Selection of the frequency meter to be used depends on the frequency range and the accuracy desired.

b. MEASUREMENT OF ANTI-RESONANCE RESISTANCE.

(1) Throw the ON-OFF switch to the ON position. Allow the C.I. Meter to warm up for 15 minutes.

(2) Set range switch S5 to the proper frequency range. If switch S5 is set to the low position, adjust rotary band switch S3 to the proper setting. If S5 is set to the high position, use rotary band switch S4 to obtain the proper setting.

(3) Insert adapter AR-1 into the proper socket.

(4) Plug the crystal unit into the socket on the top of adapter AR-1.

(5) Proceed as directed in paragraph 2a(3) through (19) above.

Note. For all anti-resonance resistance measurements, adapter AR-1 is used in conjunction with the crystal unit only. The calibrating resistors are plugged directly into the crystal socket on the meter.

c. USING CRYSTAL IMPEDANCE METER AS GO-NO GO GAGE, RESONANCE OPERATION. - The Go-No Go method described below is to be used only as a rapid method for production testing of a quantity of crystal units. This method is to be used with the understanding that it has inherent inaccuracies; results obtained from using this method should be checked against accurate measurements obtained by the previously outlined methods to determine if the Go-No Go accuracy is sufficient for the intended use. When using this method, make sure that all crystal units being tested are of the same frequency, the only variation being in their values of effective resistance.

(1) Switch the ON-OFF switch to the ON position. Allow the C.I. Meter to warm up for 15 minutes.

(2) Set range switch S5 to the desired frequency range. If switch S5 is set to the low position, adjust rotary band switch S3 to the specific range desired. If S5 has been set to the high position, use rotary band switch S4 to obtain the proper setting.

(3) Adjust the crystal drive level according to information given in the specification covering the specific crystal unit under test. Where no definite drive level has been established, the crystal unit should be maintained at as low a level as possible. This is done by advancing the METER SHUNT control to its extreme clockwise position; then advance the SCREEN VOLTAGE control to a position which will give an adequate grid current meter reading (approximately half-scale).

(a) A more accurate method of setting drive level, when the correct drive is known, is first to determine the average effective resistance of a small quantity of production crystals, using the resonance resistance method described in paragraph 2a above.

(b) Substitute a calibrating resistor of this effective resistance value in the socket of the meter. Set the METER SHUNT control fully clockwise; use the SCREEN VOLTAGE control to adjust the drive level by the method outlined below.

(c) Determine the correct drive level for the crystal unit and use the formula below to calculate the voltage drop across the resistor that corresponds to this drive level.

$$E = \sqrt{PR}$$

where:

P = drive level, in watts, and
R = average resonance crystal resistance, in ohms.

Note. For a method of measuring the voltage, E, refer to paragraph 2a(7)(c).

(4) Insert crystal unit into the socket.

(5) Adjust the proper tuning control for a maximum grid current meter reading. It may be necessary to adjust the METER SHUNT control for a convenient on-scale reading.

CAUTION

DO NOT DISTURB THE SETTING OF SCREEN VOLTAGE CONTROL AS THIS SETTING SHOULD REMAIN FIXED FOR THE REMAINDER OF THE TEST.

(6) Connect r-f cable assembly W2 from r-f output jack J1 to a radio receiver equipped with a bfo. Turn on the bfo. Obtain an approximate measurement of the crystal frequency by zero-beating the signal from C.I. Meter with that of the bfo of the receiver. Read the frequency from the receiver tuning dial or calibration chart.

(7) Substitute a calibrating resistor in the socket with a value that corre-

sponds to the maximum resistance permissible for the crystal unit (as indicated in the applicable crystal unit specification).

(a) Adjust the tuning control of the C.I. Meter so that the signal is at or near zero-beat with the frequency as measured in paragraph (6) above.

(b) Adjust the METER SHUNT control to obtain a convenient meter reading. This adjustment should remain fixed throughout the remainder of the test. Note the grid current value; regard this value as the passing activity level.

(8) Remove the resistor from crystal socket.

(9) Proceed to test crystals by plugging one unit at a time into the crystal socket and noting the grid current value. Crystal units exhibiting a greater grid current meter reading than obtained in paragraph (7)(b) above, pass the activity requirements; those showing less fail.

(10) This procedure must be repeated each time the crystal unit type or frequency is changed.

d. PROCEDURE FOR USING CRYSTAL IMPEDANCE METER MODEL 531 AS GO-NO GO GAGE, ANTI-RESONANCE OPERATION. - This procedure is identical with the instructions given for using the meter as a Go-No Go gage, resonance operation, with this change: for all anti-resonance operations, the crystal unit must be used in conjunction with adapter AR-1, where use of the crystal unit is specified.

## SECTION IV

## THEORY OF OPERATION

### 1. CRYSTAL PARAMETERS, GENERAL.

a. PIEZOELECTRIC EFFECT. - When an electrical stress is applied to a cut quartz crystal in the direction of one of the major axes, a mechanical stress is produced at right angles to this axis. Conversely, a mechanical stress along a major axis will cause electrical charges to appear on the faces of the crystal perpendicular to the stress axis. The polarity of the electrical stress and the direction of the corresponding mechanical force are interrelated; a reversal in one causes a reversal in the other. This relationship between electrical stress and mechanical force is termed the piezoelectric effect and provides a means of relating mechanical vibrations to electrical circuits.

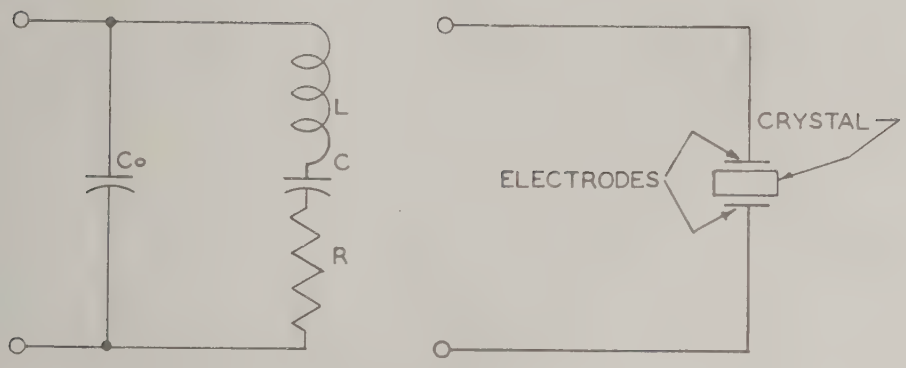



*Figure 5. Equivalent Electrical Circuit of a Piezoelectric Crystal*

b. RESONANCE. - An alternating voltage applied across a quartz crystal will cause the crystal to vibrate; if the frequency of the applied alternating voltage approximates a frequency at which mechanical resonance can exist in the crystal, the amplitude of the vibrations will be very large. Any crystal has several such resonant frequencies that depend on the crystal dimensions, the type of oscillation involved, and the orientation of the plate cut from the natural crystal.

c. PROPERTIES OF PIEZOELECTRIC RESONATOR. - A good piezoelectric resonator possesses the following properties: a low-temperature coefficient of resonant frequency, a high piezoelectric activity (performance index), and a frequency spectrum containing only one resonant frequency in the vicinity of the desired oscillation. Temperature can alter the frequency of mechanical resonance through its effects on the density, the linear dimensions, and the moduli of elasticity of the crystal. Since some of the elastic constants are positive, while others are negative, the temperature coefficient of frequency may be either positive, negative, or zero, according to the mode of oscillation, the orientation of the crystal plate, and the shape of the plate. The electrical circuit associated with a vibrating crystal is shown in figure 5. The capacity, $C_0$, represents the electrostatic capacity between the crystal electrodes when the crystal is in place but not vibrating; the series combination of L, C, and R represents the equivalent mass, compliance, and frictional loss of the vibrating crystal, respectively.

## 2. CRYSTAL PARAMETERS, MEASUREMENT.

a. STATIC CAPACITANCE, $C_0$. - The value of the static capacitance of the crystal unit, $C_0$, may be measured by any conventional capacitance measuring unit.

If this measurement is made by using a Q meter or an r-f bridge, be careful to select a frequency of operation somewhat lower than the crystal unit frequency.

b. RESONANCE AND ANTI-RESONANCE RESISTANCES. - The measurement of the effective resistance in ohms at resonance is outlined in the operational procedure (para. 2a). The measurement of the effective resistance in ohms at anti-resonance is outlined in the operational procedure (para. 2b).

c. SERIES CAPACITANCE, C. - Use the following equation to calculate the capacitance, C, of the series arm of the crystal unit:

$$C \text{ (in farads)} = \frac{2(C_0 + C_1)\Delta F}{F}$$

where:

$\Delta F$ = the difference between the anti-resonance frequency and the resonance frequency ($F_a - F_s$) in cps,
$F$ = the nominal frequency of the crystal unit in cps,
$C_0$ = the static capacitance of the crystal unit in farads, and
$C_1$ = the load capacitance in farads.

d. INDUCTANCE, L. - Use the following equation to calculate the inductance, L, in the series arm of the crystal:

$$L \text{ (in henries)} = \frac{1}{(2\pi F)^2 C}$$

where:

$F$ = the nominal frequency of the crystal unit in cps, and
$C$ = series capacitance of the crystal unit in farads.

e. VOLTAGE ACROSS CRYSTAL UNIT. - The voltage may be measured as outlined in paragraph 2a(7)(c). Resonance and anti-resonance present two different cases as follows:

(1) Series resonance.

$$E = E_d = RI$$

where:

$E$ = voltage across the crystal,
$E_d$ = difference between the two voltmeter readings,

R = effective resonance resistance in ohms (para. 2a), and,
I = r-f crystal current in amperes.

(2) Anti-resonance resistance.

$$E = \frac{E_d}{2\pi FC_1R_e} = \frac{I}{2\pi FC_1}$$

where:

$E_d$ = difference between the two voltmeter readings,
F = nominal frequency of the crystal unit in cps,
$C_1$ = load capacitance in farads,
$R_e$ = effective anti-resonance resistance in ohms (para. 2b), and,
$2\pi$ = 6.28 (a constant).

f. PERFORMANCE INDEX (PI). - The PI of the crystal unit also may be calculated from the equation:

$$PI = \frac{X_e^2}{R_e} = \frac{1}{(2\pi FC_1)^2R_e}$$

where:

$$X_e = \frac{1}{2\pi FC_1}$$

3. CRYSTAL IMPEDANCE METER.

Crystal Impedance Meter Model 531 measures the equivalent circuit parameters of a piezoelectric crystal in the frequency range of 10.0 to 140.0 mc. The C.I. Meter consists of two tuned-plate, tuned-grid variable frequency oscillator circuits; each covering two of the specified frequency ranges, with switches to permit the use of either circuit (figures 6, 7, and 8), and a conventional power supply (figure 9). The crystal under test, or any one of twelve fixed calibrating resistors in the range from 10 to 150 ohms, can be made part of a feedback network. The magnitude of the oscillations is indicated by the panel meter on the microampere scale.

4. FUNCTIONING OF CRYSTAL IMPEDANCE METER.

a. GENERAL.

(1) The Crystal Impedance Meter is essentially a tuned-plate, tuned-grid oscillator circuit (figures 6, 7, and 8) in which the crystal unit to be tested is placed in the feedback path. The crystal unit thus controls the oscillation frequency of the circuit and the amplitude of oscillation. The effective resistance of the crystal

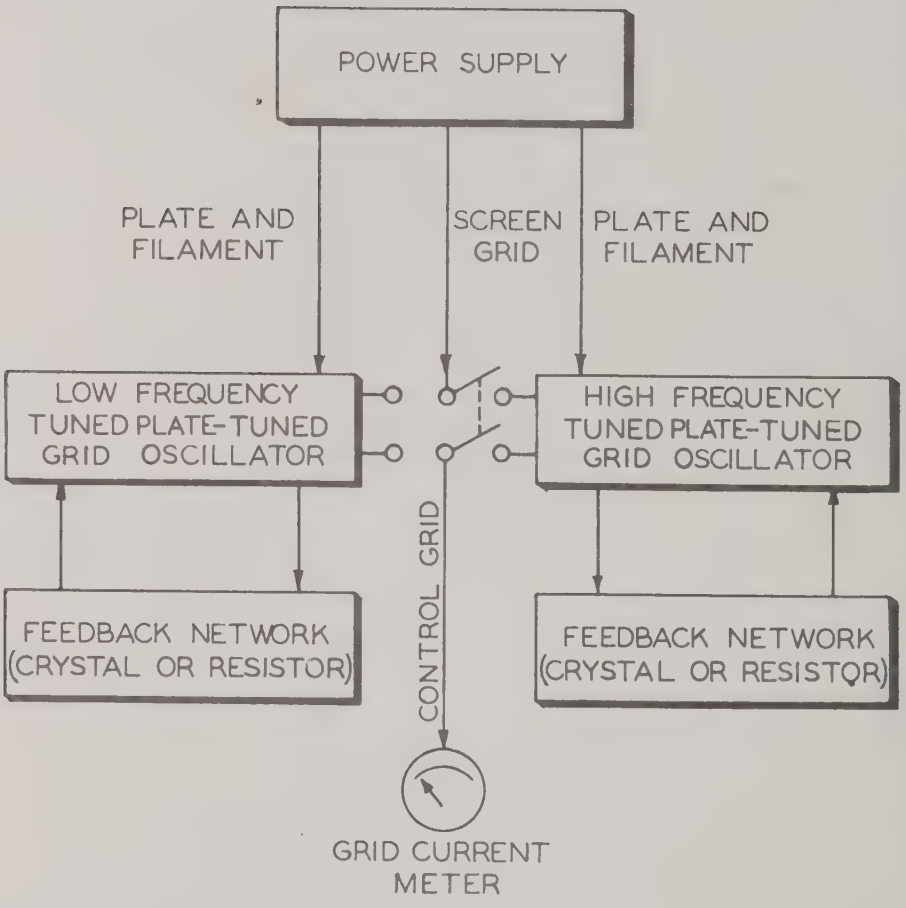



*Figure 6. Block Diagram of Crystal Impedance Meter Model 531*

unit is measured by application of the following principle of substitution: In any system, if an element of the system is removed and a substitute element is inserted, so that the original set of boundary conditions is satisfied and no new ones are added, then the substitute element is equivalent operationally to the original element. Thus, if the boundary conditions (oscillation frequency and amplitude of oscillation) are measured at some point in the circuit, a network of resistance and reactance is substituted for the crystal unit without changing the boundary conditions; then the network represents the crystal unit at that particular frequency and amplitude of oscillation. The crystal unit may be operated at either its resonance frequency or at its anti-resonance frequency.

(2) At resonance, the equivalent electrical circuit (figure 5) of the crystal unit is purely resistive. At anti-resonance, the equivalent electrical circuit of crystal unit is inductive. Thus, if the crystal unit is operated at its anti-resonance frequency, and if the correct value of load capacitance (C1) is connected in series with the crystal unit, the combination of the crystal unit and load capacitance appears as a pure resistance at the correct operating frequency. Therefore, in either case, a resistance may be substituted for the crystal unit or for the combination of crystal unit and load capacitance; this resistance can be adjusted to such a value that the oscillation frequency and amplitude are the same as they were before the substitution was made. This value of resistance is, therefore, the effective resonance resistance (R) or the effective anti-resonance resistance ($R_e$).

(3) In actual use, the exact resonance or anti-resonance frequency may be unknown; this information, however, is not necessary. The circuit of the Crystal Impedance Meter (connected to appropriate frequency measuring equipment) is tuned first to the approximate frequency; then, by alternate adjustment of the value of the substitution resistance and of the circuit tuning, the correct frequency and value of resistance are obtained. Generally, adjustment must be made only two or three times before complete satisfaction of the boundary conditions is attained. These adjustments may be compared with the resistance and reactance adjustments performed when balancing an impedance bridge.

b. POWER SUPPLY.

(1) The power supply (figure 9) is a conventional type that converts 115 or 230 volts a-c, 50 to 1,000 cps to the regulated voltage necessary for the plate and screen grid of oscillator tube V1 or V2. The power supply used rectifier tube V3 (5Y3GT) in a full-wave circuit and tube V4 (OA2) as a voltage regulator. A 1-ampere fuse (F1) opens the circuit if an overload or short occurs inside the C.I. Meter. VOLTAGE CHANGE-OVER switch S2 adapts the unit for operation on either 115 or 230 volts a-c, 50 to 1,000 cps by connecting the two halves of the primary winding in parallel or in series.

(2) Transformer T1 has a primary rating of 115 or 230 volts a-c, single-phase, with output windings on the secondary of 700 volts at 35 ma center-tapped for the plates of V3, 5.0 volts at 3.0 amperes for the filament of V3, and 6.3 volts at 2.5 amperes for the filaments of V1, V2, and pilot lamp E1. The rectified voltage is taken off one side of the filament of rectifier tube V3.

(3) The rectified output of V3 is filtered free of ripple by resistors R11, R12, and R13 and capacitors C17A and C17B. The filter is connected to voltage-dropping resistor R14 which, in turn, is connected to voltage regulating tube V4. The tube V4, operating in conjunction with resistor R14, maintains the voltage across its terminals constant at approximately 150 volts, despite normal changes in line voltage and current drain of the connected circuits. If the voltage across this gaseous regulator rises, the tube will draw more current; this causes a greater voltage drop across R14 and keeps the voltage at the plate (pin 5) of V4 constant. If the line voltage drops because of outside causes, less current will be drawn by

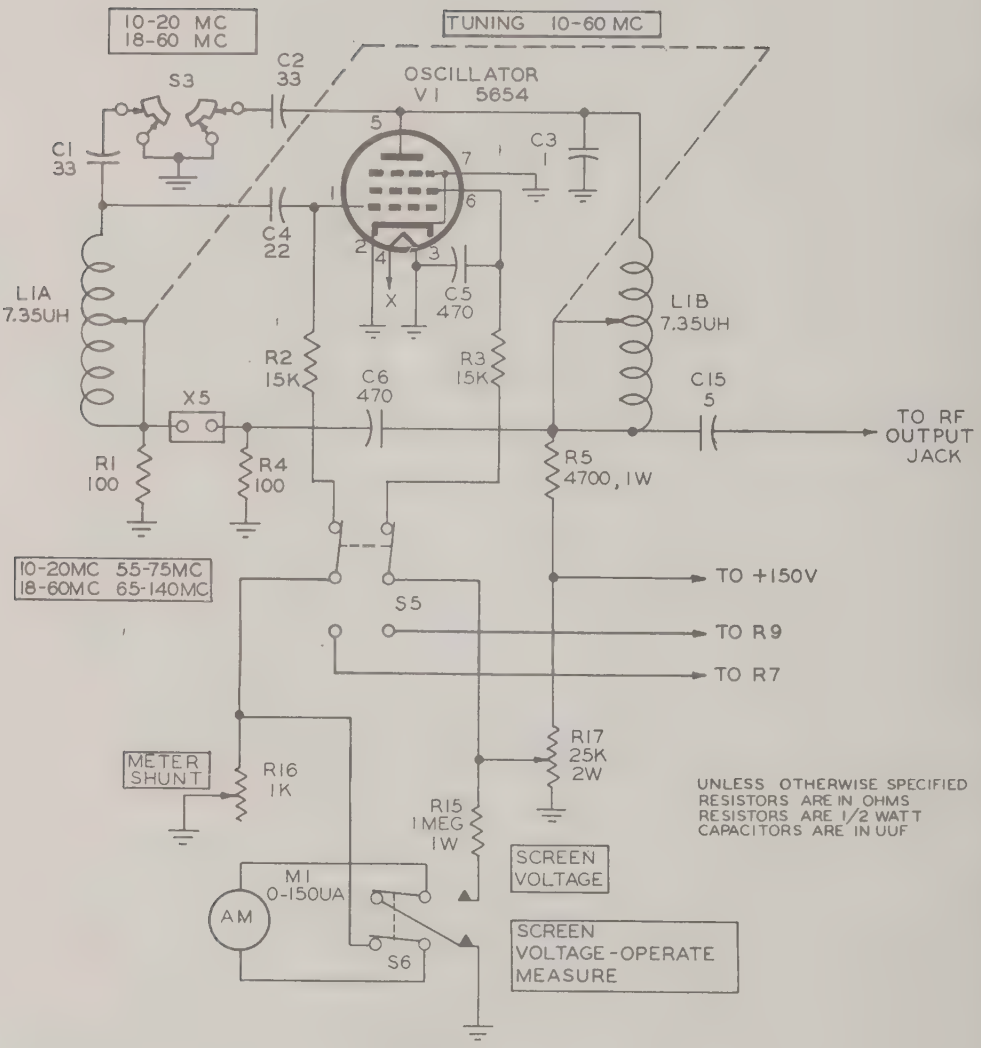



*Figure 7. Simplified Schematic Diagram of Low-Frequency Oscillator*

tube V4, the voltage across R14 will be smaller, and the voltage at the plate (pin 5) of tube V4 will be constant.

(4) The screen grid of the oscillator tube in use is supplied with d-c voltage controlled by potentiometer R17 (SCREEN VOLTAGE) connected across the voltage regulator tube V4. This screen grid voltage controls the amplitude of oscillations. Pilot lamp E1 is operated from the 6.3-volt winding of the secondary of transformer T1. The .003-uf capacitor C18 bypasses r-f current from the input a-c power line to ground. The 500-uuf capacitor C14 prevents r-f currents of the plate circuit from flowing in the power supply circuit. A complete schematic diagram is shown in figure 17.

## 5. OSCILLATOR CIRCUIT.

a. GENERAL. - The oscillator circuits (figures 7 and 8) use r-f pentode tubes type 5654 (V1 and V2) operating as class C amplifiers. The feedback path provided by either a crystal or a calibrating resistor converts the amplifier in use to a class C oscillator. The frequency bands (four) are selected with frequency range switch S5 and rotary band switches S3 and S4. Switch S5 connects screen-grid potential to oscillator tube V1 or V2, and also connects the panel microammeter in the grid circuit of the same tube. The other switches, S3 and S4, set the bands covered by the two oscillators. When switch S3, associated with the lower frequency oscillator, is in the 10-20 mc position, capacitors C1 and C2 are connected in parallel with the grid and plate tuning inductors, coil L1A and coil L1B, respectively, to obtain the tuning band specified. When switch S3 is operated to the 18-60 mc position, capacitors C1 and C2 are removed from the circuit leaving only the circuit-distributed capacitance across grid inductor L1A and the circuit-distributed capacitance, plus capacitor C3, across plate inductor L1B. Similarly, when switch S4, associated with the higher frequency oscillator, is in the 55-75 mc position, capacitors C7 and C8 are connected in parallel with the grid and plate tuning inductors, L2A and L2B, respectively, to obtain the tuning band specified. When switch S4 is operated to the 65-140 mc position, capacitors C7 and C8 are removed from the circuit. The two oscillator circuits are continuously variable throughout their bands by their tuning controls; TUNING 10-60 mc control drives the low-frequency tuning dial and varies the inductance of coils L1A and L1B, and TUNING 55-140 mc drives the high-frequency tuning dial and varies the inductance of coils L2A and L2B. Output jack J1 (figure 15) is connected to the plate tuning circuits of the two oscillators through coupling capacitors C15 and C16.

Note. The functioning of the two oscillator circuits is identical except for the frequency bands covered. Only the functioning of the lower frequency unit will, therefore, be discussed in detail. For this discussion, it is assumed that frequency range switch S5 has been set to the low position.

(1) When control grid (pin 1) is driven positive during a cycle of oscillation, a rectified current flows through the 15,000-ohm grid leak resistor R2 and the grid current meter, (the sensitivity of which is adjusted by METER SHUNT potentiometer R16), to ground. Capacitor C4 blocks the rectified control grid current from flow-

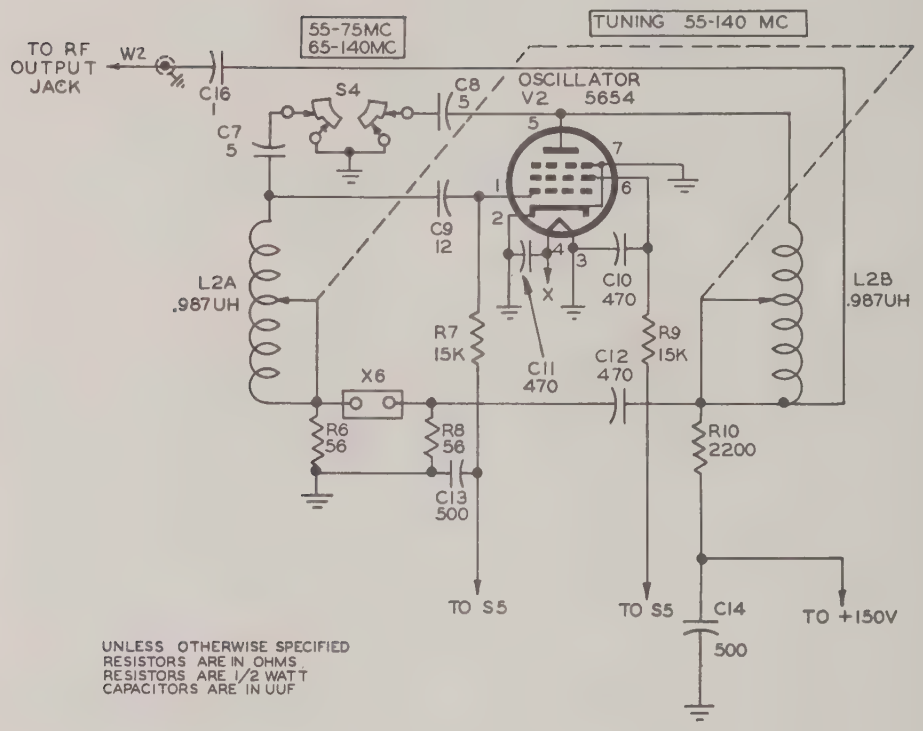



*Figure 8. Simplified Schematic Diagram of High-Frequency Oscillator*

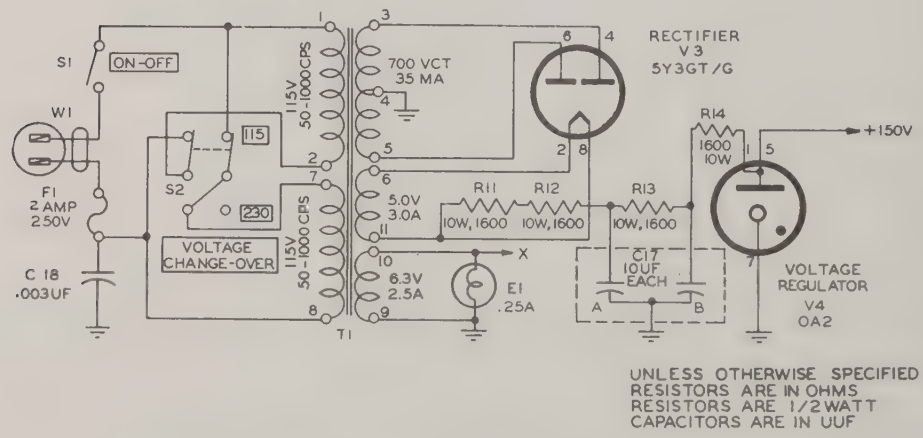



*Figure 9. Simplified Schematic Diagram of Power Supply of Crystal Impedance Meter Model 531*

ing through the grid tank circuit which consists of r-f variable coil L1A paralleled by the circuit distributed capacitance for the higher frequency band and with the added capacitance of C1 when S3 is in the lower frequency band position. In the plate circuit of the tube, d-c (direct-current) plate current flows through the voltage dropping resistor R5 and the variable tuning inductor L1B to the plate. Coil L1B with associated capacitance tracks in frequency with grid coil L1A. The screen-grid positive d-c voltage obtained from potentiometer R17 (SCREEN VOLTAGE), connected across the voltage regulator tube V4, controls the amplitude of oscillation. Capacitor C5 bypasses r-f from screen-grid to ground. The cathode (pin 2) and the suppressor (pin 7) are connected to ground, reducing the likelihood of output-input circuit feedback through the tube.

(2) The higher frequency oscillator, covering the bands 55-75 mc and 65-140 mc, differs from the lower frequency oscillator as follows: A two-section, spiral type, variable inductance tuner is used. Because of the frequency bands covered, the inductance of the tuner coils L2A and L2B is considerably less than the lower frequency coils. Smaller loading capacitors C7 and C8 are shunted across the tuning inductances by switch S4 when operation in the 55-75 mc band is desired. A plate circuit compensating capacitor corresponding to C3 is not required. The grid blocking capacitor C9 is smaller, as are crystal load resistors R6 and R8 and the plate voltage dropping resistor R10. The theory of operation is the same as for the lower frequency oscillator.

## 6. FEEDBACK NETWORK.

When an adequate feedback path is provided and the screen-grid potential is increased to a satisfactory value, the circuit oscillates. The feedback path (figure 7) is through crystal socket X5. This socket also is used when the calibrating resistors are substituted for the crystal being measured. The 470-uuf capacitor C6 provides a low-impedance path for the r-f voltage developed across resistor R5 by the r-f current generated in the tuned plate tank circuit of tube V1. Capacitor C6 also provides the necessary phase relation for the r-f feedback voltage to the grid circuit. The feedback voltage is injected into the grid circuit across voltage dividing resistor R1. (Adapter AR-1 is provided with the C.I. Meter. This plugs into crystal socket X5 or X6. It contains a 32.0-uuf capacitor in series with a crystal socket and is used for anti-resonance resistance measurements which are made in the same manner as resonance resistance measurements. The resistance determined by using the adapter is the approximate anti-resonance resistance of the crystal unit operating into a 32.0-uuf load capacitance.) A resistance substitution method is used when making both resonance and anti-resonance resistance measurements, calibrating resistors (fixed values) in the range between 10 and 150 ohms being plugged into the crystal sockets on the panel. The calibrated resistor selected should give most nearly the same frequency and amplitude of oscillation as the oscillating crystal unit. Amplitude of oscillation is indicated on the grid current meter. The approximate crystal resistance is that of the selected calibrating resistor. The crystal sockets will accommodate any two-pin crystal holder having .050 inch pins with .486 inch center-to-center spacing.

## SECTION V
## AUXILIARY EQUIPMENT

### 1. FREQUENCY MEASUREMENT EQUIPMENT.

a. STANDARD FREQUENCY TEST RACK. - The C.I. Meter may be coupled to a standard frequency test rack to measure the exact frequency of crystal units. The standard frequency test rack (Frequency Measuring Assembly CY-93/FSM-1) (fig. 10) consists of the items listed below:

Bfo radio receiver.
Selected inductance coil and its associated coil (graph for use in the bfo receiver).
Oscilloscope.
Interpolation oscillator.
Power pack (receiver).
Loudspeaker.
Multivibrator unit.
Antenna.
Power supply.

b. ALTERNATE EQUIPMENT. - Alternate frequency measuring equipment may be used in place of the equipment listed above.

(1) A calibrated radio receiver may be used. The degree of accuracy will be low, however, because of the frequency variation that commonly is found in such radio circuits.

(2) Frequency Meter Set SCR-211, covering a calibrated range from 125 kc (kilocycles) to 20 mc, may be used in an emergency to supply the frequency standard in place of the multivibrator unit or interpolation oscillator. It may be used directly for measurements of crystals with frequencies between 10 and 20 mc or with a frequency divider, such as Frequency Divider TS-711/U, for indirect measurements of crystals with frequencies between 20 and 140 mc. Its main function, however, is to tune and to calibrate radio receivers in a net to given frequency. Frequency Meter TS-174/U, covering a calibrated range from 20 to 280 mc, may be used directly for measurements of crystals with frequencies between 20 and 140 mc.

(3) A comparison oscillator and deviation meter may be substituted for the interpolation oscillator. Lack of frequency stability and accuracy of calibration makes this equipment less desirable than the interpolation oscillator.

(4) A test rack assembly consisting of a Radio Receiver R-140/TSM-1, a heterodyne frequency meter (General Radio type 720-A), or equivalent, a heterodyne frequency meter (General Radio type 620-A) and calibrator, or equivalent, and an interpolating frequency standard (General Radio type 1110-A), or equivalent, may be used for measurements between 10 and several hundred mc.

## 2. PROCEDURES FOR MEASURING FREQUENCIES ACCURATELY.

### a. USING FREQUENCY DIVIDER TS-711/U.

(1) GENERAL. - When using a set-up such as that described in paragraph 1b(2), with the Frequency Divider TS-711/U, the frequencies of crystals in the range handled by Crystal Impedance Meter Model 531 may be measured with good accuracy. Make the connections as indicated in figure 12. Plug in the a-c line cords and allow all units to warm up for at least 15 minutes.

(2) CRYSTAL FREQUENCY MEASUREMENTS. - Crystal frequencies are measured under either resonance or anti-resonance conditions. The measuring procedures are the same except that the C.I. Meter adjustments are different. A check measurement of a 108.6 mc crystal will be outlined.

(a) Insert the crystal in the higher frequency crystal socket on the C.I. Meter panel. Adjust the C.I. Meter for proper operation at resonance (Section III, para. 2a) or anti-resonance (Section III, para. 2b). Set the METER SHUNT for the INPUT TUNING METER and the METER SHUNT for the LOCK INDICATOR on the Frequency Divider TS-711/U to their maximum counter-clockwise position (minimum meter indications). Set the INPUT range selector switch to the 70-200 mc position. Adjust the 70-200 mc input tuning control until the INPUT TUNING METER indicates a peak current. (If there is no current, turn the METER SHUNT of the

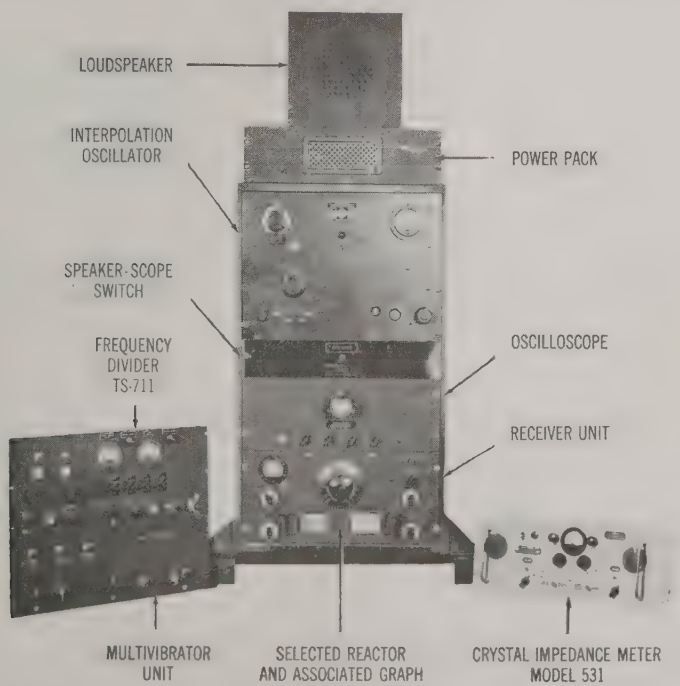



*Figure 10. Crystal Resistance and Frequency Measuring Equipment Including Frequency Divider TS-711/U*

INPUT TUNING METER clockwise until the meter deflects to any convenient value. When peaking, do not permit the meter to deflect off-scale.)

(b) Set the START AT STAGE switch to the stage in which will be found one-half the crystal frequency, in this case 108.6 divided by 2 or 54.3 mc. This will be the 40-80 mc switch position. Set INDICATOR METER AT switch to the 40-80 mc switch position. Turn the METER SHUNT control of the LOCK INDICATOR clockwise until the meter reads about half-scale (or any convenient value). Adjust the tuning control of the 40-80 mc stage until a sudden sharp increase in the LOCK INDICATOR meter reading is noted. Tune for peak current but use the METER SHUNT control to prevent the meter from deflecting off-scale. The first frequency division by two is now accomplished.

(c) Set the INDICATOR METER AT switch to the next (20-40 mc) stage position. Adjust the tuning control of this stage until a sudden sharp increase in the LOCK INDICATOR meter reading is noted. Tune for peak current but keep the meter reading on the scale, as explained in paragraph (b) above, by the use of the METER SHUNT. The second frequency division (divided by 2) is now accomplished. The input frequency has been reduced to $\frac{108.6}{4}$ mc.

(d) Set the INDICATOR METER AT switch to the 10-20 mc stage position. Adjust the tuning, as before, for a peak LOCK INDICATOR meter reading. This effects a third frequency division by 2 and reduces the input frequency to $\frac{108.6}{8}$ mc.

(e) Turn the INDICATOR METER AT switch clockwise to the last (5-10 mc) stage position. Adjust the tuning for a peak LOCK INDICATOR meter reading. The output of Frequency Divider TS-711/U is equal to the input frequency divided by 2 for each divider stage utilized, or, in this case, to $\frac{108.6}{16}$ or 6.79 mc. Note that this is merely the result of arithmetical division of a crystal frequency assumed to be 108.6. Use Frequency Meter Set SCR-211 to obtain the accurate frequency of the crystal by measuring the output frequency from the frequency divider and multiplying by 16.

Note. When adjusting the tuning of the frequency divider stages, more than one point may be found where a sharp upswing in the LOCK INDICATOR meter reading is obtained. Adjust the tuning to the point giving the greatest (optimum) increase.

(f) Using the Frequency Meter Set SCR-211, follow the procedure for measurement of local transmitter, (approximate frequency known) adapting the procedure as follows:

(1) Correct the variable frequency oscillator to the crystal check point nearest the approximate frequency.

(2) Loosely couple the frequency meter to the frequency divider and turn the operating switch to the proper operating position.

*Figure 11. Crystal Impedance Meter Model 531 with Frequency Divider TS-711/U*

(3) Move the frequency meter tuning control to the zero-beat point that most closely approximates the setting given for the approximate frequency.

(4) Multiply this frequency by 16 to obtain the frequency of the crystal unit in the C.I. Meter.

(g) If any doubt exists as to the approximate frequency of the crystal, this frequency should be established by using an absorption type wavemeter or a radio receiver.

CAUTION

ALWAYS CONNECT THE OUTPUT OF FREQUENCY DIVIDER TS-711/U TO ANT POST OF THE FREQUENCY METER SET SCR-211 BEFORE CORRECTING THE CALIBRATION OF THE METER TO THE CRYSTAL CHECK POINT. THIS WILL ELIMINATE THE EFFECT OF THE FREQUENCY SHIFT CAUSED BY THE CONNECTION LEAD.

b. USING COMMERCIAL TEST RACK ASSEMBLY.

(1) GENERAL. - When using a set-up such as described in paragraph b(4) above and C.I. Meter, the frequencies of the crystals in the range handled by

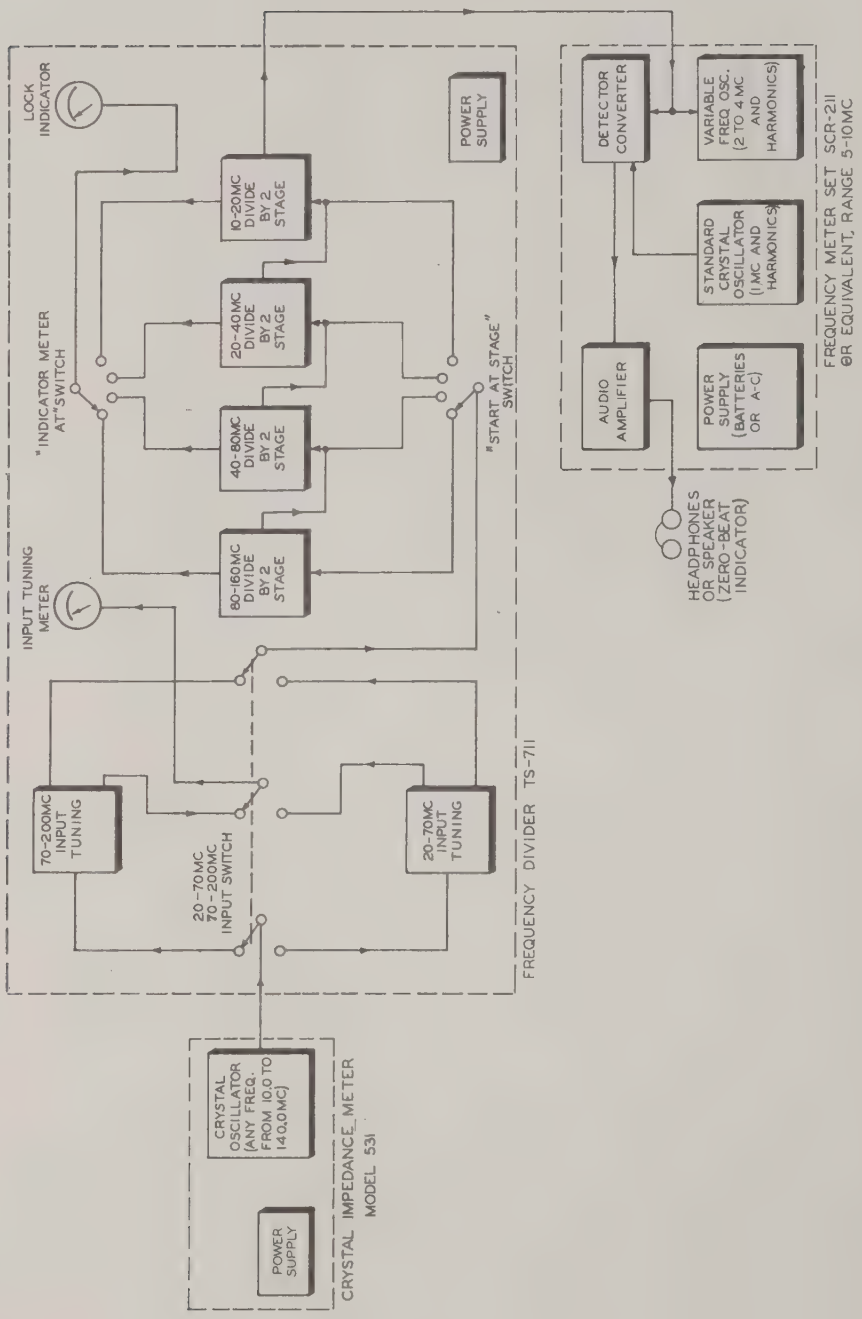

LOCK INDICATOR
"INDICATOR METER AT" SWITCH
INPUT TUNING METER
10-20MC DIVIDE BY 2 STAGE
20-40MC DIVIDE BY 2 STAGE
40-80MC DIVIDE BY 2 STAGE
80-160MC DIVIDE BY 2 STAGE
POWER SUPPLY
"START AT STAGE" SWITCH
70-200MC INPUT TUNING
20-70MC 70-200MC INPUT SWITCH
20-70MC INPUT TUNING
FREQUENCY DIVIDER TS-711
DETECTOR CONVERTER
VARIABLE FREQ OSC. (2 TO 4 MC AND HARMONICS)
STANDARD CRYSTAL OSCILLATOR (1 MC AND HARMONICS)
AUDIO AMPLIFIER
POWER SUPPLY (BATTERIES OR A-C)
FREQUENCY METER SET SCR-211 OR EQUIVALENT, RANGE 5-10MC
HEADPHONES OR SPEAKER (ZERO-BEAT INDICATOR)
CRYSTAL OSCILLATOR (ANY FREQ. FROM 10.0 TO 140.0 MC)
POWER SUPPLY
CRYSTAL IMPEDANCE METER MODEL 531

*Figure 12. Accurate Frequency Measuring Set-up Using Crystal Impedance Meter Model 531 with Frequency Divider TS-711/U*

the C.I. Meter may be measured with good accuracy. Apply power to all units in the test set-up; allow the equipment to warm up for at least 15 minutes. Proceed as instructed in paragraph (2) below.

(2) PRELIMINARY CHECKING OF EQUIPMENT. - Make sure that the accuracy of the measuring equipment is checked and that adjustments are made to minimize any errors.

(a) Tune in WWV on any available frequency in the range 5.0 mc to 20.0 mc. Turn off the beat-frequency oscillator of the receiver. Set headphone switch S1 (if used) to position 1 for this operation. (If a switch is not used, plug the phones into the jack on Radio Receiver R-140/FSM-1.)

(b) With switches S2, S3, and S5 in the OFF position, turn switch S4 to position 2. Set the dial of the interpolating frequency standard (General Radio type 1110-A) to 0 (corresponding to a basic output of 1,000 kc). Adjust the internal crystal oscillator, following instructions given with the instrument, for a zero-beat in the headphones. Observe the precaution of making this zero-beat adjustment only during periods when WWV transmission is unmodulated. (It is possible to obtain the zero-beat, since all standard frequency carriers transmitted by WWV are evenly divisible by 1,000 kc, the basic frequency of one of the multivibrators in the frequency standard. One of the multivibrator harmonics will, therefore, zero-beat against any WWV carrier frequency.) When this zero-beat is completed, the frequency standard is ready for use in precision frequency measurements.

(c) Check the heterodyne frequency meter (General Radio type 720-A) calibration against the frequency standard. To do this, turn switch S1 to position 2, turn switches S2, S3, and S4 to the OFF position, and close switch S5. With the interpolating frequency standard (General Radio type 1110-A) dial set at exactly 0 for a basic output of 1,000 kc (1.0 mc), zero-beats should be obtained against the harmonics of the 1 mc multivibrator at all integral multiples of this frequency on the heterodyne frequency meter (General Radio type 720-A) dial. While no frequency-correcting adjustment is provided in the heterodyne frequency meter (General Radio type 720-A), this test indicates that the unit is operating satisfactorily.

(d) Check the heterodyne frequency meter (General Radio type 620-A) and calibrator against the interpolating frequency standard (General Radio type 1110-A). The procedure is similar to that for the heterodyne frequency meter (General Radio type 720-A). To do this, turn switch S1 to position 3, turn switch S2 to position 1, and turn switches S3, S4, and S5 to the OFF position. The 620-A Frequency Meter is adjusted to cover a basic frequency range from 10 to 11 mc, with the internal crystal calibrator off. With the interpolating frequency standard (General Radio type 1110-A) dial set at exactly 0 for a basic output of 1,000 kc, zero-beats should be obtained against the harmonics of the 1,000 kc multivibrator at all integral multiples of this frequency on the heterodyne frequency meter (General Radio type 620-A) dial. (As an alternate check, turn switch S1 to position 1 and switch S2 to position 2. The output of the heterodyne frequency meter (General Radio type 620-A) now can be zero-beat in Radio Receiver R-140/FSM-1 against

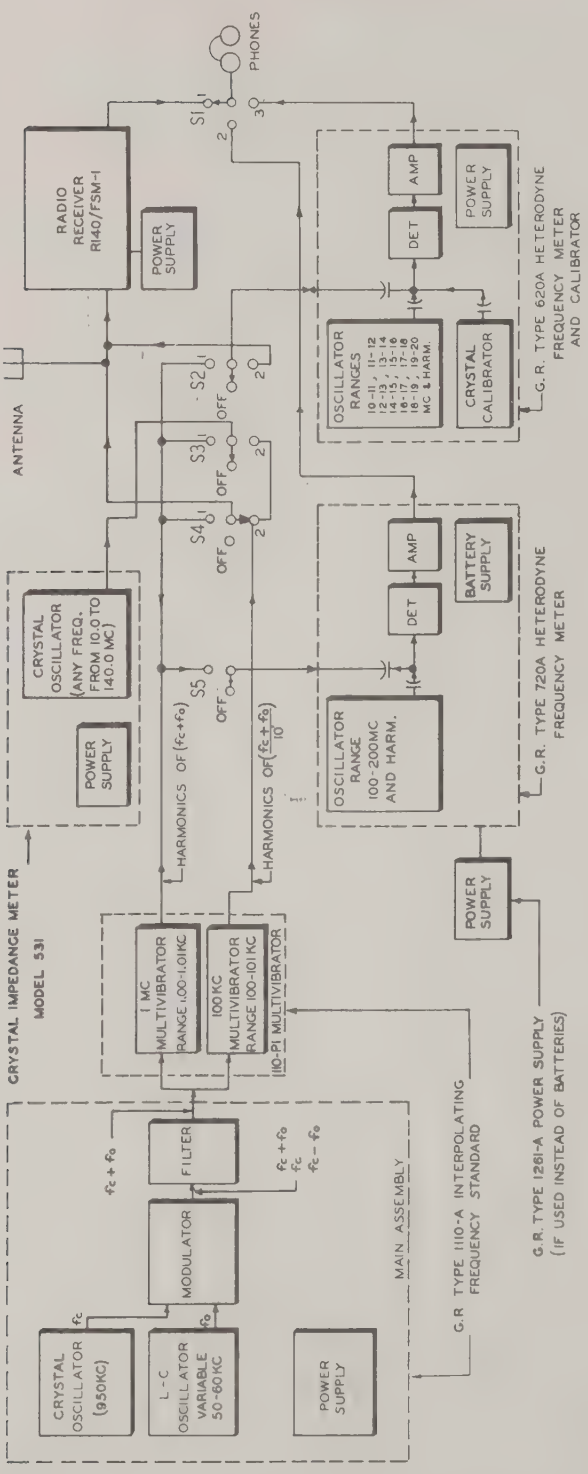



*Figure 13. Frequency Measuring Set-up Using Crystal Impedance Meter Model 531 and General Radio, or Equivalent, Standard Equipment*

any available 10, 15, or 20 mc carrier frequency of WWV.) The frequency delivered by the heterodyne frequency meter (General Radio type 620-A) should agree with that of WWV.

(3) CRYSTAL FREQUENCY MEASUREMENTS. - The harmonics of the heterodyne frequency meter (General Radio type 620-A) and calibrator can be used for all crystal frequencies in the range 10 to 140 mc, but less chance of error will result if this unit is restricted to the 10 to 100 mc range and the heterodyne frequency meter (General Radio type 720-A) is used for higher frequencies. The 620-A unit, however, is usable when the 720-A unit is unavailable. It is possible to substitute frequency meters such as Frequency Meter Set SCR-211 and Frequency Meter TS-174/U for the General Radio units mentioned. In connection with the use of the interpolating frequency standard (General Radio type 1110-A), the generic terms, 100 kc multivibrator and 1 mc multivibrator have been used. These multivibrators are of the controlled type and are locked in with the variable frequency output of the oscillators. As the tuning dial of the frequency standard is varied from 1,000 kc to 1,010 kc (its full frequency range), the 100 kc multivibrator fundamental will vary simultaneously from 100 to 101.0 kc and all harmonics generated by the multivibrator will be multiples of the corresponding value. Similarly, as the tuning dial of the frequency standard is varied from 1,000 kc to 1,010 kc, the 1 mc multivibrator fundamental will vary simultaneously from 1.00 to 1.01 mc and all harmonics generated will be multiples of the corresponding value. The terms, 100 kc and 1 mc applied to these multivibrators, while not specific, are convenient for description.

(a) Crystal frequencies are measured under either resonance or anti-resonance conditions. The measuring procedures are the same except that the C.I. Meter adjustments are different. A check measurement of a 108.6 mc crystal unit will be outlined.

(b) Insert the crystal in the higher frequency crystal jack on the panel of C.I. Meter and couple the output cable to the frequency measuring set-up (fig. 13). (Switches are shown on the schematic but coaxial jacks, patch cords, or any other method of making the interunit connections may be used; this depends on the permanency of the installation, available material, etc. Lone connections, whether cable or open wire, should be avoided because of possible losses, pick-up, radiation, etc.) Adjust the C.I. Meter for proper operation for resonance (Section III, para. 2a) or anti-resonance (Section III, para. 2b). Connect the headphones to the output of the heterodyne frequency meter (General Radio type 720-A) by turning switch S1 to position 2. Turn switches S2 and S4 to the OFF position, S3 to position 1, and close switch S5. Slowly turn the tuning knob of the heterodyne frequency meter (General Radio type 720-A), keeping the dial in the vicinity of 100-110 mc. An audible beat should be heard in the headphones because the C.I. Meter crystal oscillator heterodynes with the 720-A oscillator. Turn off the 100 kc and 1,000 kc multivibrator switches on the interpolating frequency standard (General Radio type 1110-A) while obtaining this beat note. Adjust the tuning knob for zero-beat; at this point, the two frequencies are identical. The dial of the 720-A meter now will indicate the frequency as 108.6 mc to an accuracy of 0.1 per cent. (The crystal unit frequency now has been shown to be between 105 and 110 mc because of the

reading of the C.I. Meter tuning dial; the fundamental of the 720-A oscillator, therefore, is being utilized, and not the second or a higher harmonic.)

(c) Turn switch S3 to the OFF position. Turn the 100 kc and 1,000 kc multivibrator switches to the ON position. Vary the tuning control of the interpolating frequency standard (General Radio type 1110-A) slowly until a zero-beat is obtained against the 720-A oscillator. Read the dial of the frequency standard accurately. It is known, from the 720-A dial setting and the 1,000 to 1,010 kc basic tuning range of the interpolating frequency standard (General Radio type 1110-A), that the 108th harmonic of a frequency between 1,000 and 1,010 kc, which equals an accurate frequency near 108.6 mc, is being used. Assume that the zero-beat occurs when using 550-1,000 of the 1,000 division dial. By using a table on the frequency standard panel and by simple computations, it is determined that the frequency of the crystal in the C.I. Meter is 108 x 1,005.50 kc or 108,594.0 kc. The accuracy of measurement is ±10 ppm (parts per million) or better.

(4) Frequency measurements of lower frequency crystals, in the range of 10 to 20 mc, require the use of the heterodyne frequency meter (General Radio type 620-A) and calibrator and the 100 kc multivibrator in the type 1110-A interpolating frequency standard (General Radio type 1110-A). The procedure is similar to that outlined above.

## SECTION VI

## MAINTENANCE

### 1. GENERAL.

Periodic inspection should be made to see that all screws are tight. If trouble should develop in the sealed meter (M1), it should be replaced from the factory and no attempt made to repair it.

### 2. LUBRICATION.

a. GENERAL. - The following precautions should be observed when the Crystal Impedance Meter Model 531 is lubricated:

(1) Do not use excessive amounts of oil or grease and do not allow connections to become greasy.

(2) Be sure that lubricants and points to be lubricated are clean and free from sand, grit, or dirt. These abrasives are the chief cause of bearing wear and

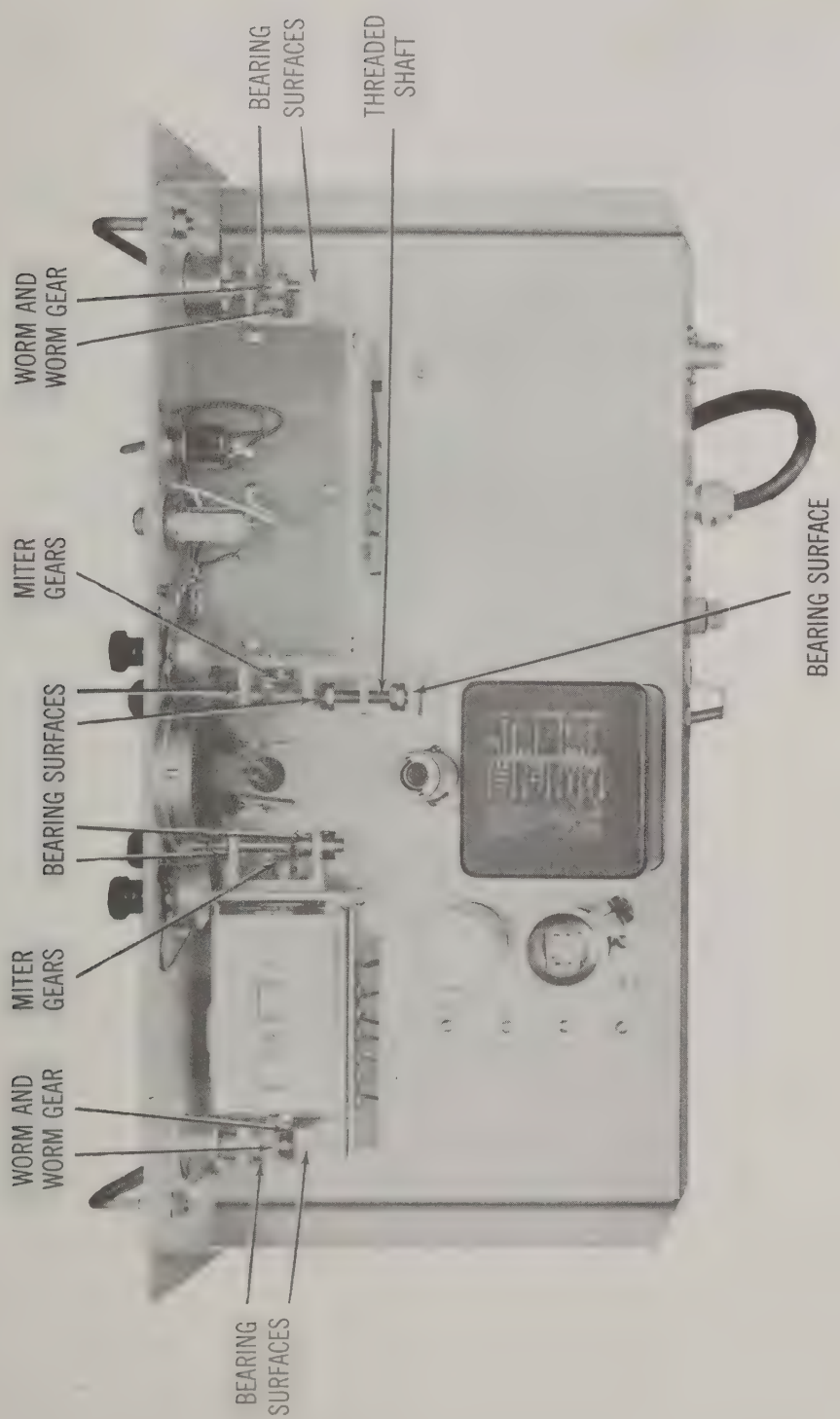



*Figure 14. Lubrication Points of Crystal Impedance Meter Model 531*

their presence often necessitates bearing replacements. Before lubricating, clean all surfaces with a lint-free cloth dampened with a solvent. Keep the solvent off surrounding parts.

b. LUBRICATION INSTRUCTIONS. - Lubrication points are illustrated in figure 14.

(1) Lubrication is performed during manufacture, and with normal care lubrication is ordinarily not required during the life of the equipment. If the equipment is completely overhauled, lubricate in accordance with the information in figure 14 and paragraph c.

(2) Gasoline should not be used as a cleaning fluid for any purpose. When the unit is overhauled or repairs are made, clean the parts with a solvent such as carbontetrachloride.

c. PARTS LUBRICATED BY THE MANUFACTURER. - The following chart lists the parts of the equipment which have been lubricated by the manufacturer prior to delivery of the equipment:

| COMPONENT | PARTS LUBRICATED | LUBRICANT |
|---|---|---|
| Crystal Impedance Meter Model 531. | Teeth of all gears, both oscillator units. | Lubri-plate. |
| | Bearings of both tuning knob and indicating dial shafts. | Oil, engine (SAE 20). |
| | Two end bearings of low-frequency (L1A and L1B) tuning indicator shaft. | Oil, engine (SAE 20). |
| | Threaded portion of low-frequency tuning shaft. | Oil, engine (SAE 20). |

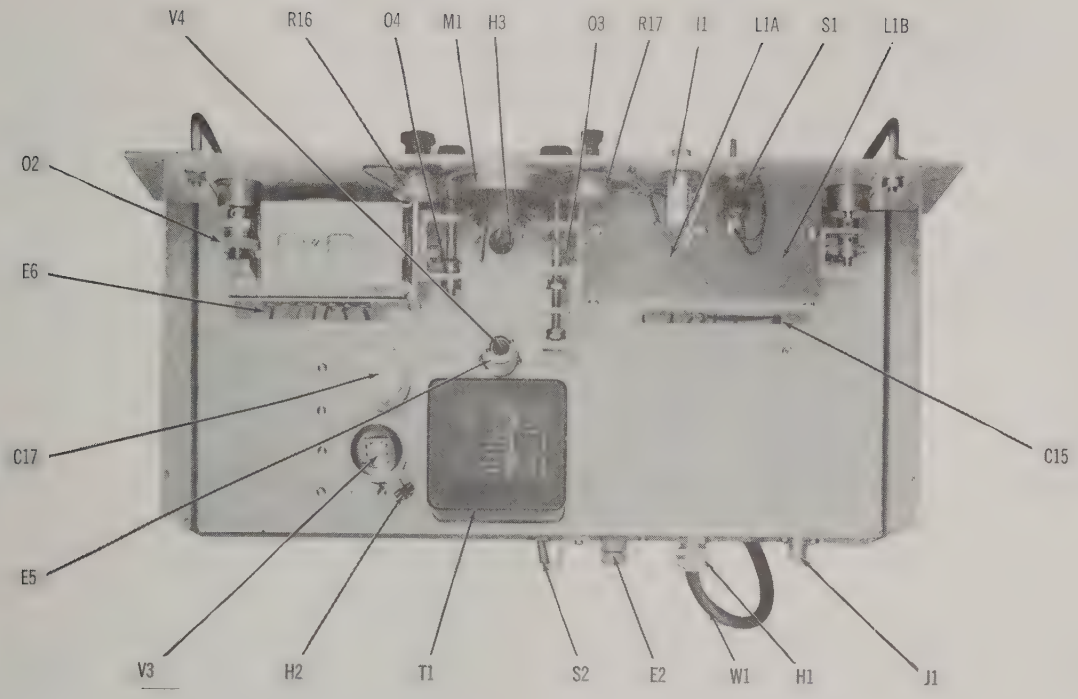



*Figure 15. Top View of Panel and Chassis Assembly of Crystal Impedance Meter Model 531*

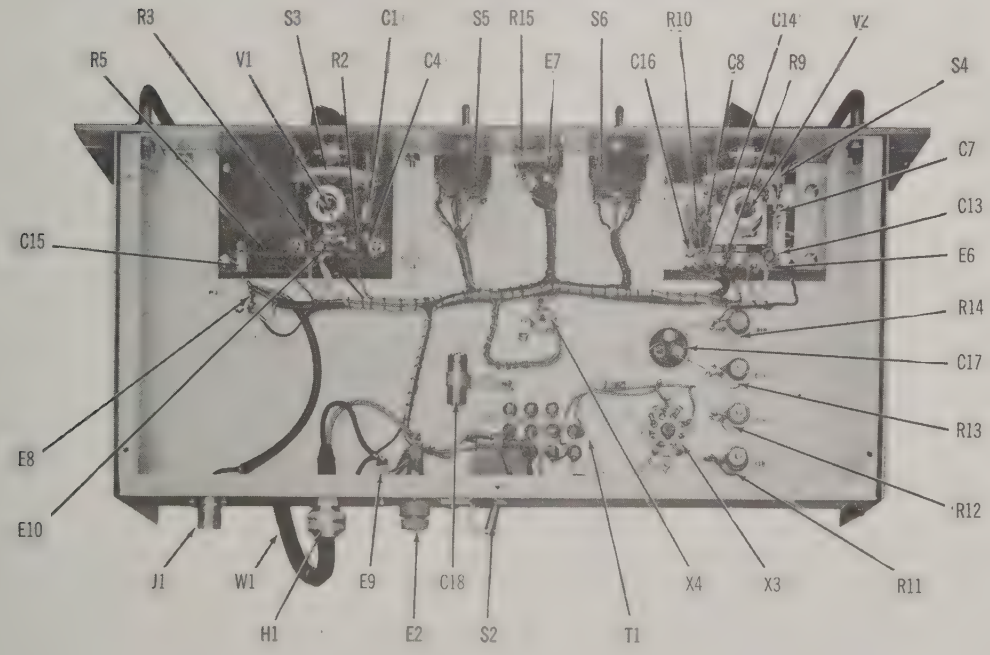



*Figure 16. Bottom View of Panel and Chassis Assembly of Crystal Impedance Meter Model 531*

d. PARTS NOT REQUIRING SUBSEQUENT LUBRICATION.

| COMPONENT | PARTS LUBRICATED | LUBRICANT | REASON SUBSEQUENT LUBRICANT IS NOT REQUIRED |
|---|---|---|---|
| Crystal Impedance Meter Model 531. | Low-frequency tuning inductor L1A and L1B end collector rings. | Lube-Rex Lubri-plate (General Cement Co.) or equivalent. | Under ordinary service conditions factory lubrication should last for life of unit. |
| | Low-frequency tuning inductor L1A and L1B contact wheels and shafts. | Lube-Rex Lubri-plate (General Cement Co.) or equivalent. | Under ordinary service conditions factory lubrication should last for life of unit. |
| | High-frequency tuning inductor L2A and L2B sliding contacts. | Lube-Rex Lubri-plate (General Cement Co.) or equivalent. | Under ordinary service conditions factory lubrication should last for life of unit. |

3. TROUBLE SHOOTING.

WARNING

WHEN SERVICING THE CRYSTAL IMPEDANCE METER MODEL 531 BE EXTREMELY CAREFUL. HIGH VOLTAGE IS PRESENT. ALWAYS DISCONNECT THE LINE PLUG BEFORE MAKING RESISTANCE CHECKS IN THE METER. BEFORE TOUCHING ANY PART AFTER THE VOLTAGE IS SHUT OFF, SHORT THE PART TO CHASSIS.

a. TROUBLE SHOOTING PROCEDURES.

(1) SECTIONALIZATION AND LOCALIZATION. - The first step in servicing defective test equipment is to sectionalize the fault. Sectionalization means tracing the fault to the major component or circuit responsible for the abnormal operation of the set. The second step is to localize the fault. Localization means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned out resistors and shorted transformers, can be located by sight or smell. The majority of faults may be located by checking voltage and resistance.

(2) TESTS. - The tests listed below aid in isolating the source of trouble. Remember that servicing procedure should cause no further damage to the test equipment. First, trouble should be localized to a single stage or circuit in the equipment. Then the trouble may be isolated within that stage or circuit by appropriate voltage, resistance and continuity measurements.

Through this inspection alone the repairman frequently discovers the trouble or determines the stage in which the trouble exists. This inspection is valuable in order to avoid additional damage which might occur through improper servicing methods and to forestall future failures.

(3) OPERATIONAL TESTS. - The operational tests are important because they frequently indicate the general condition of trouble. In many instances this information will indicate the exact nature of the fault. In order for this information to be utilized fully, all symptoms must be interpreted in relation to another.

The trouble shooting symptoms listed in the chart on page 41 will aid in localizing trouble.

(4) INTERMITTENTS. - In all these tests the possibility of intermittents should not be overlooked. This type of trouble may appear when the set is tapped or jarred. Look for loose connections. It is possible that the trouble is not in the set itself but in the installation, such as cord connections, etc.

## 4. VOLTAGE MEASUREMENTS.

Voltage measurements are an almost indispensable aid to the repairman because most trouble either results from abnormal voltages or produces abnormal voltages. Voltage measurements are always made between two points in the circuit and the circuit need not be interrupted. Complete information on normal operating voltages is given in the chart on page 44.

(1) Unless otherwise specified, voltages are measured between the indicated points and ground.

(2) Always begin by setting the voltmeter on the highest range in order that the voltmeter will not be overloaded and then, if necessary, set the voltmeter to a lower range.

## 5. VOLTMETER LOADING.

It is essential that the voltmeter resistance be at least ten times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a voltage lower than the actual voltage present when the voltmeter is removed from the circuit.

(1) To minimize voltmeter loading in high resistance circuits, use the

highest voltmeter range. The decreased loading caused by the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.

(2) The voltage and resistance charts, Tables 6-2 and 6-3, are based on readings taken with a 20,000 ohm-per-volt meter. If a 20,000 ohm-per-volt meter is used in testing for the voltage, it is not necessary to consider the effect of loading.

## 6. RESISTANCE MEASUREMENTS.

When a fault develops in a circuit its effect will very often show up as a change in the resistance values. Table 6-3 indicates the normal resistance values as measured at the tube sockets. These values are measured between the indicated points and ground unless otherwise stated. Before making any resistance measurements, turn off the power. If the ohmmeter is connected to a circuit which already has voltage in it, the meter may be damaged.

**CAUTION**

**ALWAYS DISCHARGE HIGH VOLTAGE CAPACITORS BEFORE MAKING RESISTANCE MEASUREMENTS.**

## 7. GENERAL PRECAUTIONS.

Whenever the C. I. Meter is serviced, carefully observe the following precautions.

a. Be careful when the instrument is removed from its cabinet, dangerous voltages are exposed.

b. Careless replacement of parts often causes new faults. Therefore, observe the following points:

(1) Before a part is unsoldered, note the position of the leads. If the part, such as a transformer, has a number of connections, tag each of the leads to it.

(2) Be careful not to damage other leads by pulling or pushing them out of the way.

(3) Do not allow drops of solder to fall into the set since they may cause short circuits.

(4) A carelessly soldered connection may create a new fault. It is very important to make well soldered joints since a poorly soldered joint is one of the most difficult faults to find.

## 8. TROUBLE SHOOTING CHART.

The following chart is supplied as an aid in locating trouble in the C. I. Meter.

This chart lists the symptoms which the repairman observes while making a few simple tests. The chart also indicates how to localize trouble quickly to individual stages of the C.I. Meter. Once the trouble has been localized to a stage or circuit, voltage and resistance measurements of this stage or circuit should be sufficient to isolate the defective part. Normal voltage and resistance measurements are given in Tables 6-2 and 6-3.

TABLE 6—1. TROUBLE SHOOTING CHART

| SYMPTOM | POSSIBLE TROUBLE | CORRECTION |
|---|---|---|
| 1. Pilot lamp does not light. | a. Cord not plugged into a-c source, or open. | a. Check at source and at unit. |
| | b. Fuse F1 blown out. | b. Check and replace. |
| | c. Pilot lamp E1 burned out. | c. Check and replace. |
| | d. ON-OFF switch S1 defective. | d. Check and replace. |
| | e. VOLTAGE CHANGE-OVER switch S2 defective. | e. Check and replace. |
| | f. Transformer T1 open. | f. Check and replace. |
| 2. Pilot lamp lights dimly (on 115 volt source). | a. VOLTAGE CHANGE-OVER switch S2 set for 230 v. | a. Set correctly. |
| Voltage regulator tube V4 does not light. | b. Regulator tube defective. | b. Check and replace. |
| | c. Rectifier tube V3 defective. | c. Check and replace. |
| | d. R11, R12, R13, or R14 open. | d. Check and replace. |
| | e. High-voltage winding of T1 open. | e. Check and replace. |

TABLE 6—1. TROUBLE SHOOTING CHART, (CONT'D)

| SYMPTOM | POSSIBLE TROUBLE | CORRECTION |
|---|---|---|
| | f. Capacitor C17A or C17B shorted. | f. Check and replace. |
| | g. Capacitor C14 shorted. | g. Check and replace. |
| 3. No apparent reading or deflection of grid current meter (with calibrating resistor in socket). | a. Oscillator tube V1 or V2 not oscillating. | a. Check and replace. See if tuning dial is within tuning range. |
| | b. METER SHUNT set too low. | b. Turn METER SHUNT control clockwise. |
| | c. SCREEN VOLTAGE control set too low. | c. Turn SCREEN VOLTAGE control clockwise. |
| | d. SCREEN VOLTAGE control defective (open). | d. Check and replace. |
| | e. Wiring shorted or open. | e. Check continuity. |
| | f. Meter open, transformer open, or oscillator coil open. | f. Check resistances as shown in Table 6-3. Check voltage as shown in Table 6-2. |
| | g. Contact wheels on L1A and L1B not tracking. | g. Slide wheels along shafts until they arrive within 1/4 turn of opposite ends of L1A and L1B as traveling stop on tuning shaft reaches locknuts. |

TABLE 6—1. TROUBLE SHOOTING CHART, (CONT'D)

| SYMPTOM | POSSIBLE TROUBLE | CORRECTION |
|---|---|---|
| 4. Oscillates without crystal or calibrating resistor in panel socket. | a. Wiring disturbed in feedback or oscillator circuits. | a. Restore any wires which were disturbed while trouble shooting or repairing to their original positions. |
| | b. Tube shield removed. | b. Replace shield. |
| | c. Tuning shaft on low-frequency oscillator grounded. | c. Remove tuning shaft from ground. |
| 5. Stop on low-frequency tuning does not function. | Locknuts loose. | Adjust locknuts to meet requirement in step 3g above. |

## 9. D-C RESISTANCE OF TRANSFORMER.

The d-c resistances of transformer T1 should correspond to the following:

| TERMINALS | OHMS |
|---|---|
| 1-2 (with connection to S2 opened) | 20 |
| 7-8 (with connection to S2 opened) | 20 |
| 3-4 | 320 |
| 4-5 | 320 |
| 6-11 (rectifier V3 removed from socket) | .1 |
| 9-10 (oscillator tubes V1 and V2 and lamp E1 removed from sockets) | .2 |

## TABLE 6—2. VOLTAGE CHART

All measurements taken to ground with a 20,000 ohm-per-volt multimeter.

| COMPONENT PART | TERMINAL | VOLTAGE TO GROUND (d-c) |
|---|---|---|
| C17A | (pos)+ | 250 |
| C17B | (pos)+ | 195 |
| V1 | 1 | -.15 (S5 at low-frequency range; R16 fully clockwise) |
| V1 | 5 | 85 |
| V1 | 6 | 83 (S5 at low-frequency range; R17 fully clockwise) |
| V2 | 1 | -.10 (S5 at high-frequency range; R16 fully clockwise) |
| V2 | 5 | 118 |
| V2 | 6 | 85 (S5 at high-frequency range; R17 fully clockwise) |
| V3 | 2 | 320 |
| V4 | 1 or 5 | 150 (Tube lighted) |

## TABLE 6—3. RESISTANCE CHART

| COMPONENT PART | TERMINAL | RESISTANCE TO GROUND (ohms) |
|---|---|---|
| T1 | 10 | .2 |
| V1 | 1 | 16K (S5 at low-frequency range; R16 fully clockwise) |
| V1 | 5 | 32K |

TABLE 6—3. RESISTANCE CHART, (CONT'D)

| COMPONENT PART | TERMINAL | RESISTANCE TO GROUND (ohms) |
|---|---|---|
| V1 | 6 | 42K (S5 at low-frequency range; R17 fully clockwise) |
| V2 | 1 | 16K (S5 at high-frequency range; R16 fully clockwise) |
| V2 | 5 | 32K |
| V2 | 6 | 42K (S5 at high-frequency range; R17 fully clockwise) |
| V3 | 4 | 320 |
| V3 | 6 | 320 |

Note. Measure the d-c resistance of the primary circuit of the power transformer from prong to prong on the a-c plug. With switch S1 closed, the resistance should be about 10 ohms with switch S2 in the 115-volt position and about 40 ohms with S2 in the 230-volt position.

## 10. TROUBLE SHOOTING BY USING EQUIPMENT PERFORMANCE CHECK LIST.

a. GENERAL. - The equipment performance check list is to be followed in numerical sequence. It lists the items to be checked, the normal indications of effect to be expected, and the corrective measures to be taken.

b. ACTION OR CONDITION. - This column indicates what is to be done to the control or part mentioned in the item column.

c. NORMAL INDICATIONS. - The normal indications listed include the visible signs that the operator should perceive when checking the items. If indications are not normal, the operator should apply the recommended corrective measures.

d. CORRECTIVE MEASURES. - The corrective measures listed are those the operator can make without turning the equipment in for repairs.

e. EQUIPMENT PERFORMANCE CHECK LIST.

## TABLE 6—4. EQUIPMENT PERFORMANCE CHECK LIST

| | ITEM NO. | ITEM | ACTION OR CONDITION | NORMAL INDICATIONS | CORRECTIVE MEASURES |
|---|---|---|---|---|---|
| PREPARATORY | 1 | Line cord. | Plugged into socket of a-c power source. | | |
| | 2 | VOLTAGE CHANGE-OVER switch S2. | Place in proper position for power supply voltage. | | |
| | 3 | SCREEN VOLTAGE control R17. | Set to full clockwise position. | | |
| | 4 | METER SHUNT control R16. | Set to full clockwise position. | | |
| | 5 | R-f output cable assembly W5. | Connect from jack J1 on rear of chassis to receiver of frequency meter. | | |
| START | 6 | ON-OFF switch S1. | Turn to ON position. | Panel lamp lights. | Check plug and line cord. Check fuse F1. Check panel lamp. Check voltage source. Check transformer T1. |
| | 7 | Range switch S5. | Set to low-frequency range. | | |
| | 8 | Rotary band switch S3. | Set to 10-20 MC position. | | |
| | 9 | 100-ohm calibrating resistor. | Plug into crystal socket below nameplate. | Meter should read 30 ua or higher between 10 to 20 mc. | Refer to Section VI. |

TABLE 6—4. EQUIPMENT PERFORMANCE CHECK LIST, (CONT'D)

| | ITEM NO. | ITEM | ACTION OR CONDITION | NORMAL INDICATIONS | CORRECTIVE MEASURES |
|---|---|---|---|---|---|
| EQUIPMENT PERFORMANCE | 10 | Rotary band switch S3. | Set to 18-60 MC position. | | Refer to Section VI. |
| | 11 | 100-ohm calibrating resistor. | Plug into crystal socket below nameplate. | Meter should read 30 ua or higher between 18 to 60 mc. | Refer to Section VI. |
| | 12 | Range switch S3. | Set to high-frequency range. | | |
| | 13 | Rotary band switch S4. | Set to 55-75 MC position. | | |
| | 14 | 100-ohm calibrating resistor. | Plug into crystal socket below nameplate. | Meter should read 30 ua or higher between 60 to 75 mc. | Refer to Section VI. |
| | 15 | Rotary band switch S4. | Set to 65-140 MC position. | | |
| | 16 | 100-ohm calibrating resistor. | Plug into crystal socket below nameplate. | Meter should read 30 ua or higher between 75 to 110 mc. | Refer to Section VI. |
| | 17 | SCREEN VOLTAGE MEASURE--OPERATE switch S6. | Hold in SCREEN VOLTAGE MEASURE position. Vary SCREEN VOLTAGE control. | Meter will read from 0 to 150 volts as control is varied. | Refer to Section VI. |
| STOP | 18 | ON-OFF switch S1. | Turn to OFF position. | Panel lamp goes out. Equipment goes off. | ON-OFF switch defective. Refer to Section VI. |

## 11. REPAIRS.

### a. REPLACEMENT OF PARTS.

(1) GENERAL. - When replacement of equipment is necessary because of failure of a component, follow the disassembly procedures given in paragraph (4) below. It is assumed that the dust cover and bottom cover plate have been removed during the trouble shooting procedure.

(2) RESISTORS. - The resistors are self-supporting. Unsoldering is the only procedure required for removal.

(3) FIXED CAPACITORS. - The small capacitors are self-supporting and may be removed by unsoldering. Dual electrolytic capacitor C17 is removed by unsoldering the leads and removing the capacitor mounting nut.

(4) DISASSEMBLY OF CRYSTAL IMPEDANCE METER.

(a) Loosen the set screws on all knobs and remove the knobs from the front panel. Set each dial index over one of the end graduations and record its position. Loosen the set screws in the dials and remove them from the front panel. Remove the three center screws in each dial plate and lift the dial plates off the front panel.

(b) To remove the microammeter, loosen the stud nuts, take off the wire lugs, and remove the panel screws holding the meter.

(c) To remove the low-frequency range tuning assembly (figs. 15 and 16), unsolder and tag the cabled wires to the coil unit terminal strip. Remove capacitor C15. Remove the dust cover from the tuning assembly. Unscrew the four screws holding the coil assembly to the panel. Note that one of these screws is normally hidden by the dial plate. Remove the retaining nut that secures rotary band switch S3 to the front panel and lift the switch from the panel. The low-frequency tuning assembly is now removable as a unit for replacement or repair.

(d) To remove the high-frequency range tuning assembly, unsolder and tag the cabled wires to the coil unit terminal strip. Remove the three screws that hold the coil assembly to the panel. Note that one screw is normally hidden by the dial plate. Unscrew the nut that secures rotary band switch S4 to the front panel and remove the switch from the panel.

(e) To remove ON-OFF switch S1, range switch S5, and SCREEN VOLTAGE MEASURE--OPERATE switch S6 from the front panel, remove the respective retaining nut from each switch in the same manner as for switch S3. Unsolder and tag the leads to the SCREEN VOLTAGE and METER SHUNT controls.

(f) Remove the nuts which hold the handles and the four screws which

hold the panel to the chassis. The chassis assembly is now removable for repair, if required.

(g) The Crystal Impedance Meter has now been disassembled to the point where the remaining components can be removed as desired without difficulty.

(5) REASSEMBLY PROCEDURE. - To reassemble the equipment, reverse the above procedures. Handle the two tuning assemblies carefully to avoid disarranging critical wiring.

Note. Be sure to replace the two dial plates in their original positions as directed in paragraph (4) above. Carefully align the dial plates with the indexes at the previously recorded settings.

12. ALIGNMENT PROCEDURE.

a. GENERAL. - No alignment procedure is necessary for Crystal Impedance Meter Model 531 unless either or both of the tuning assemblies require replacement.

b. EQUIPMENT USED FOR ALIGNMENT AND ADJUSTMENT. - The alignment of a C.I. Meter is established on the higher frequency band of each oscillator unit. For best accuracy, use Frequency Meter TS-174/U; this meter covers a range of 20 to 280 mc. If the frequency meter is not available, a calibrated receiver may be used. Note that the degree of accuracy obtained will be somewhat lower when using a calibrated receiver instead of the frequency meter. Headphones or a loudspeaker are needed to check the aural results obtained.

c. ALIGNMENT OF CRYSTAL IMPEDANCE METER. - Alignment of this equipment consists of establishing the correct tuning dial setting for a given frequency developed by each oscillator. Basic equipment needed is described in Section V. Since the dial calibrations are intended only to be used as rough guides to the frequencies of the oscillators, no arrangement for picking up a standard frequency transmission from WWV is required.

(1) ALIGNMENT OF LOW-FREQUENCY TUNING DIAL. - Connect r-f output cable W5 to output jack J1 on the Crystal Impedance Meter and to the input of Frequency Meter TS-174/U. Connect headphones to the frequency meter audio output. Turn on both units and allow them to warm up for 15 minutes. Position switch S5 on the C.I. Meter to the low-frequency range and rotary band switch S3 to the 18-60 mc position. Insert a 40 ohm calibrating resistor in crystal socket X5. Adjust the screen voltage to 60 volts, by means of the SCREEN VOLTAGE control, with switch S6 held in the SCREEN VOLTAGE MEASURE position. Set the tuning dial on the frequency meter to exactly 60 mc. Slowly vary the tuning control of the Crystal Impedance Meter until a zero-beat is heard in the headphones. The dial reading should be 60 mc to within the width of the indicator line. If this agreement is met, check the dial settings at 34 mc (with SCREEN VOLTAGE control at 30 volts)

and at 18 mc (with SCREEN VOLTAGE control at 25 volts) against the frequency meter at these frequencies. Tolerance should be within ±3%. If the dial on the Crystal Impedance Meter is noticeably off at 60 mc, loosen the three center screws slightly and rotate the dial plate until it reads correctly. Tighten the screws when the dial plate is properly positioned. Check the settings at 34 mc and 18 mc. If the dial cannot be made to log at the three frequencies, the contact wheels on coil L1A and coil L1B may not be tracking correctly. Refer to the trouble shooting chart (Table 6-1) for instructions necessary to correct this condition; then repeat the alignment procedure.

(2) ALIGNMENT OF HIGH-FREQUENCY TUNING DIAL. - Position switch S5 to the high-frequency range and rotary band switch S4 to the 65-140 mc position. Insert a 100 ohm calibrating resistor in crystal socket X6. Adjust the screen voltage to 130 volts, by means of the SCREEN VOLTAGE control. Set the dial of the frequency meter to 110 mc (make sure the dial is set accurately). Slowly vary the tuning control of the Crystal Impedance Meter until a zero-beat is heard in the headphones. The dial reading should be 110 mc to within the width of the indicator line. If this condition is met, check the dial settings at 90 mc (with SCREEN VOLTAGE control at 60 volts) and at 65 mc (with SCREEN VOLTAGE control at 35 volts) against the frequency meter at these frequencies. The tolerance should be within ±3%. If the dial is noticeably off at 110 mc, rotate the dial plate as previously described (para. (1) above). Check the settings at the three test frequencies after the dial plate is positioned. If the dial cannot be made to log at the three frequencies, the sliding contacts on coil L2A and L2B may not be tracking correctly. (This condition, however, will be encountered rarely because of the contact construction.) If necessary, shift the contacts by lifting them gently with a small screw driver until satisfactory tracking is obtained. Always replace the metal cover on the coil unit when the alignment check is made.

## 13. FINAL TESTING.

a. EQUIPMENT REQUIRED FOR FINAL TESTING. - The following equipment is necessary for final testing of Crystal Impedance Meter Model 531:

Frequency meters covering the range from 10 to 140 mc, as outlined in Section V.
Headphones or speaker.
Electronic Multimeter (General Radio type 1800-A or equivalent).
20,000 ohm-per-volt multimeter.

b. TESTS. - The tests below indicate whether a Crystal Impedance Meter that has been repaired meets the minimum requirements for satisfactory operation.

(1) VISUAL AND MECHANICAL INSPECTION. - Thoroughly inspect the reconditioned C.I. Meter for loose nuts and screws; mechanical fit; and operation of moving parts, controls, and fastening devices. Check wiring, soldered connections, ground connectors, and finishes for satisfactory workmanship.

(2) CONTINUITY TEST. - Make continuity tests to determine that all circuits are wired properly and that all connections make good electrical contact. When satisfied that no shorts exist, turn on the C.I. Meter and measure voltages to ground as outlined in Table 6-2.

(3) DIAL CALIBRATION. - Following procedure outlined in paragraph 12c, check the dial calibration at 60, 34, and 18 mc for the low-frequency oscillator on its higher band and at 20 and 10 mc on its lower band. Similarly, check the dial calibration at 110, 90, and 65 mc for the high-frequency oscillator on its higher band and at 75 and 55 mc on its lower band. The dials should read within ±3% at all specified frequencies. With the stated calibrating resistors in the crystal sockets oscillation should be obtained throughout the tuning ranges.

(4) AMPLITUDE OF OSCILLATION. - Plug the 100 ohm calibrating resistor into the low-frequency oscillator crystal socket. Adjust the METER SHUNT control for greatest sensitivity. Using a screen grid voltage up to the maximum, the amplitude of oscillation throughout both tuning bands to 110 mc should be great enough to develop a rectified grid current of at least 30 ua above the normal residual of about 5 to 10 ua. (Measure the residual by removing the calibrating resistor from the crystal jack.) If this requirement cannot be met, replace the oscillator tube. Plug the 100 ohm calibrating resistor into the high-frequency oscillator crystal socket and duplicate the test. The same requirement should be met, but if it cannot be met, replace the oscillator tube.

(5) SELF OSCILLATION. - With the crystal jack open, neither oscillator should show a rectified grid current above the normal residual value at any point in the tuning bands. A greater current indicates self oscillation; refer to the trouble shooting chart in Table 6-1 for correction procedures.

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| W1 | CABLE, power, electrical: 2 conductors, stranded, # 16 AWG, rubber insulation. | Power cord. | HA-3723 |
| W2 | CABLE, radio frequency: u-h-f cable; coaxial; 52-ohm characteristic impedance. | R-f output cable. | HA-3722 |
| C1 | CAPACITOR, fixed, ceramic dielectric: 33 uuf capacity, 500 vdcw. | Tuning capacitor for grid circuit of V1. | H-1007-41 |
| C2 | CAPACITOR, fixed, ceramic dielectric: Same as C1. | Tuning capacitor for plate circuit of V1. | |
| C3 | CAPACITOR, fixed, ceramic dielectric: 1 uuf capacity, 500 vdcw. | Adjusts tracking of plate circuit of V1. | H-1007-42 |
| C16 | CAPACITOR, fixed, ceramic dielectric: Same as C3. | Output coupling capacitor. | |
| C4 | CAPACITOR, fixed, ceramic dielectric: 22 uuf capacity, 500 vdcw. | Couples grid of V1 to tuning circuit. | H-1007-43 |
| C20 | CAPACITOR, fixed, ceramic dielectric: Same as C4. | Part of load capacitor. | |
| C7 | CAPACITOR, fixed, ceramic dielectric: 5 uuf capacity, 500 vdcw. | Tuning capacitor for grid circuit of V2. | H-1007-44 |
| C8 | CAPACITOR, fixed, ceramic dielectric: Same as C7. | Tuning capacitor for plate circuit of V2. | |
| C9 | CAPACITOR, fixed, ceramic dielectric: 12 uuf capacity, 500 vdcw. | Couples grid of V2 to tuning circuit. | H-1007-45 |
| C10 | CAPACITOR, fixed, ceramic dielectric: 470 uuf capacity, 600 vdcw. | Bypasses rf from screen grid of V2 to ground. | H-1007-46 |
| C11 | CAPACITOR, fixed, ceramic dielectric: Same as C10. | Bypasses rf from filament of V2 to ground. | |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| C12 | CAPACITOR, fixed, ceramic dielectric: Same as C10. | Couples plate and grid circuits of V2 in feedback loop. | |
| C15 | CAPACITOR, fixed, ceramic dielectric: 5 uuf capacity, 500 vdcw. | Output coupling capacitor. | H-1007-47 |
| C17 | CAPACITOR, fixed, electrolytic: 2 sections; 10 uf capacity per section; 450 vdcw. | Filters output of V3. | HA-3748 |
| C18 | CAPACITOR, fixed, paper dielectric: 3,000 uuf, 600 vdcw. | Bypasses rf from a-c power line. | H-1007-35 |
| C5 | CAPACITOR, fixed, mica dielectric: 470 uuf capacity, 500 vdcw. | Bypasses rf from screen grid of V1 to ground. | H-1080-31 |
| C6 | CAPACITOR, fixed, mica dielectric: Same as C5. | Couples plate and grid circuits of V1 in feedback loop. | |
| C13 | CAPACITOR, fixed, mica dielectric: 500 uuf capacity, 500 vdcw. | R-f bypass for meter M1. | HA-4496 |
| C14 | CAPACITOR, fixed, mica dielectric: Same as C13. | Keeps r-f out of power supply. | |
| C19 | CAPACITOR, variable ceramic: 3 to 12 mmf. | Adjusts load capacity. | HA-4580 |
| H2 | CLAMP, electrical: stainless steel; cap type. | Holds V3 in socket. | HA-4499 |
| P1 | CONNECTOR, plug: male. | Connects r-f cable to C.I. Meter. | HA-4930 |
| P2 | CONNECTOR, plug: 2 cont; male. | Power cable plug. | HA-4732 |
| J2 | CONNECTOR, receptacle: 1 cont, female; banana type connector. | Ground connection. | HA-3727 |
| J3 | CONNECTOR, receptacle: Same as J2. | Ground connection. | |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| J1 | CONNECTOR, receptacle: 1 cont, female, round. | Connects r-f cable assembly to C.I. Meter. | HA-4929 |
| V1 | ELECTRON TUBE: 5654. | Oscillator tube. | HA-4795 |
| V2 | ELECTRON TUBE: Same as V1. | Oscillator tube. | |
| V3 | ELECTRON TUBE: 5Y3GT. | Full-wave rectifier. | HA-4863 |
| V4 | ELECTRON TUBE: 0A2. | Voltage regulator. | HA-3665 |
| F1 | FUSE, cartridge: 2 amp, 250 v. | Line fuse. | HA-1289 |
| E2 | FUSEHOLDER: extractor post type. | Holds line fuse. | HA-4109 |
| E11 | HOLDER, resistor: plug type; accommodates and contains a 10 ohm resistor. | Calibrating resistor. | HA-4647 |
| E12 | HOLDER, resistor: plug type; accommodates and contains a 22 ohm resistor. | Calibrating resistor. | HA-4648 |
| E13 | HOLDER, resistor: plug type; accommodates and contains a 30 ohm resistor. | Calibrating resistor. | HA-4649 |
| E14 | HOLDER, resistor: plug type; accommodates and contains a 40 ohm resistor. | Calibrating resistor. | HA-4650 |
| E15 | HOLDER, resistor: plug type; accommodates and contains a 51 ohm resistor. | Calibrating resistor. | HA-4651 |
| E16 | HOLDER, resistor: plug type; accommodates and contains a 60 ohm resistor. | Calibrating resistor. | HA-4652 |
| E17 | HOLDER, resistor: plug type; accommodates and contains a 68 ohm resistor. | Calibrating resistor. | HA-4653 |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| E18 | HOLDER, resistor: plug type; accommodates and contains an 82 ohm resistor. | Calibrating resistor. | HA-4654 |
| E19 | HOLDER, resistor: plug type; accommodates and contains a 91 ohm resistor. | Calibrating resistor. | HA-4655 |
| E20 | HOLDER, resistor: plug type; accommodates and contains a 100 ohm resistor. | Calibrating resistor. | HA-4656 |
| E21 | HOLDER, resistor: plug type; accommodates and contains a 120 ohm resistor. | Calibrating resistor. | HA-4657 |
| E22 | HOLDER, resistor: plug type; accommodates and contains a 150 ohm resistor. | Calibrating resistor. | HA-4658 |
| E23 | KNOB: bakelite. | Adjusts switch S3. | HA-4355 |
| E24 | KNOB: Same as E23. | Adjusts switch S4. | |
| E25 | KNOB: round; plastic; black. | Tuning knob for low-frequency oscillator. | HA-4561 |
| E26 | KNOB: Same as E25. | Tuning knob for high-frequency oscillator. | |
| E27 | KNOB: round; plastic; black. | Control knob for R16. | HA-3730 |
| E28 | KNOB: Same as E27. | Control knob for R17. | |
| E29 | KNOB: Same as E27. | Control knob for R18. | |
| E1 | LAMP, incandescent: 6-8 v, .25 amp; miniature bayonet base; clear; white. | Indicates unit is on. | HA-3735 |
| I1 | LIGHT, panel: 1 lamp, miniature bayonet base, 6-8 v; jewel assembly. | Holds pilot lamp. | HA-3734 |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| M1 | MULTIMETER: panel mounted; dc; 0-150 ua. | Measures grid current or screen voltage. | HA-4452 |
| | OSCILLATOR, radio frequency: 10-60 mc range, 2 bands; tuned plate--tuned grid circuit. | Low-frequency oscillator. | HC-4716 |
| | OSCILLATOR, radio frequency: 55-140 mc range, 2 bands; tuned plate--tuned grid circuit. | High-frequency oscillator. | HC-4697 |
| | OSCILLATOR SUBASSEMBLY: c/o: 1 rh coil, 1 lh coil, 1 center shaft, 1 right side shaft, 1 left side shaft. | Oscillator tuning coil assembly for low-frequency oscillator. | HB-4717 |
| R15 | RESISTOR, fixed: 1 megohm, ±1% tolerance, 1 w. | Meter (M1) multiplier resistor. | H-1510-4 |
| R1 | RESISTOR, fixed comp: 100 ohms, ±5%, 1/2 w. | Crystal load resistor. | H-1009-149 |
| R4 | RESISTOR, fixed comp: Same as R1. | Crystal load resistor. | |
| R2 | RESISTOR, fixed comp: 15,000 ohms, ±5%, 1/2 w. | Grid leak resistor for V1. | H-1009-235 |
| R3 | RESISTOR, fixed comp: Same as R2. | Screen voltage dropping resistor for V1. | |
| R7 | RESISTOR, fixed comp: Same as R2. | Grid leak resistor for V2. | |
| R9 | RESISTOR, fixed comp: Same as R2. | Screen voltage dropping resistor for V2. | |
| R6 | RESISTOR, fixed comp: 56 ohms, ±5%, 1/2 w. | Crystal load resistor. | H-1009-236 |
| R8 | RESISTOR, fixed comp: Same as R6. | Crystal load resistor. | |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| R10 | RESISTOR, fixed comp: 2,200 ohms, ±5%, 1/2 w. | Load resistor in tuned plate circuit of V2. | H-1009-237 |
| R5 | RESISTOR, fixed comp: 4,700 ohms, ±5%, 1 w. | Load resistor in tuned plate circuit of V1. | H-1009-248 |
| R11 | RESISTOR, fixed, WW: 1600 ohms, ±5%, 10 w. | Filters output of V3. | H-1100-117 |
| R12 | RESISTOR, fixed, WW: Same as R11. | Filters output of V3. | |
| R13 | RESISTOR, fixed, WW: Same as R11. | Filters output of V3. | |
| R14 | RESISTOR, fixed, WW: Same as R11. | Filters output of V3 and regulates plate voltage of V1 and V2. | |
| R16 | RESISTOR, variable: 1000 ohms, 2 w. | Adjusts sensitivity of meter (M1). | HA-5373 |
| R17 | RESISTOR, variable: 25,000 ohms, 2 w. | Adjusts screen voltage of V1 and V2. | HA-5374 |
| R18 | RESISTOR, variable: 100 ohms, 2 w nominal power rating. | Variable resistance adapter. | HA-4742 |
| E3 | SHIELD, electron tube. | Shield for tube V1. | HA-4730 |
| E4 | SHIELD, electron tube: Same as E3. | Shield for tube V2. | |
| E5 | SHIELD, electron tube. | Shield for tube V4. | HA-4731 |
| X1 | SOCKET, electron tube: 7 contact. | Socket for tube V1. | HA-4498 |
| X2 | SOCKET, electron tube: Same as X1. | Socket for tube V2. | |
| X4 | SOCKET, electron tube: Same as X1. | Socket for tube V4. | |

TABLE 6—5. TABLE OF REPLACEABLE PARTS

| SYMBOL | DESCRIPTION | FUNCTION | R.F.L. PART NO. |
|---|---|---|---|
| X3 | SOCKET, electron tube: octal. | Socket for tube V3. | HA-3733 |
| X5 | SOCKET, crystal: .050 in. dia pins accommodated; .486 in. spacing c to c. | Crystal socket. | HA-4558 |
| X6 | SOCKET, crystal: Same as X5. | Crystal socket. | |
| E8 | STRIP, 2 terminal. | Term. connection strip. | HA-4681 |
| S1 | SWITCH, toggle: single pole, single throw; 15 amp; 125 v ac. | Power ON and OFF | HA-3709 |
| S2 | SWITCH, toggle: double pole, double throw; 25 amp; 125 v ac. | Selects power transformer (T1) primary voltage, 115 or 230 volts. | HA-3710 |
| S5 | SWITCH, toggle: Same as S2. | Connects high or low frequency oscillator into circuit. | |
| S6 | SWITCH, toggle: double pole, double throw: 15 amp; 125 v ac spring return. | Connects meter (M1) to grid or screen circuits. | HA-4492 |
| S3 | SWITCH, rotary: 1 section; 2 positions. | Adjusts frequency range of low frequency oscillator. | HB-4453 |
| S4 | SWITCH, rotary: Same as S3. | Adjusts frequency range of high frequency oscillator. | |
| T1 | TRANSFORMER, power: 115/230 v ac; 50 to 1000 cyc; single phase primary windings; secd #1 - 700 v CT at 35 ma; secd #2 - 6.3 v at 2.5 amp; secd #3 - 5 v at 3 amp. | Power Transformer. | HC-4466 |

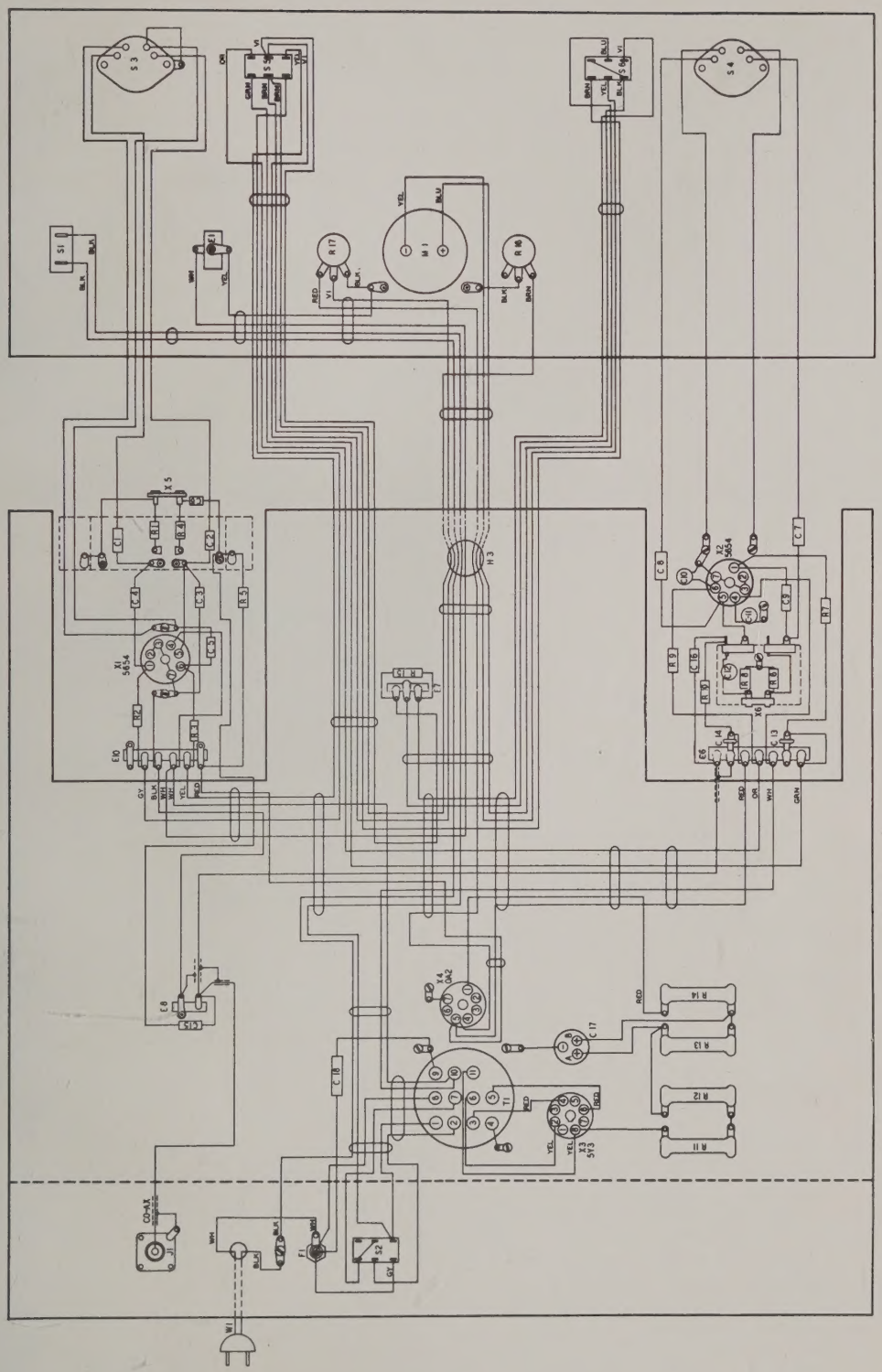
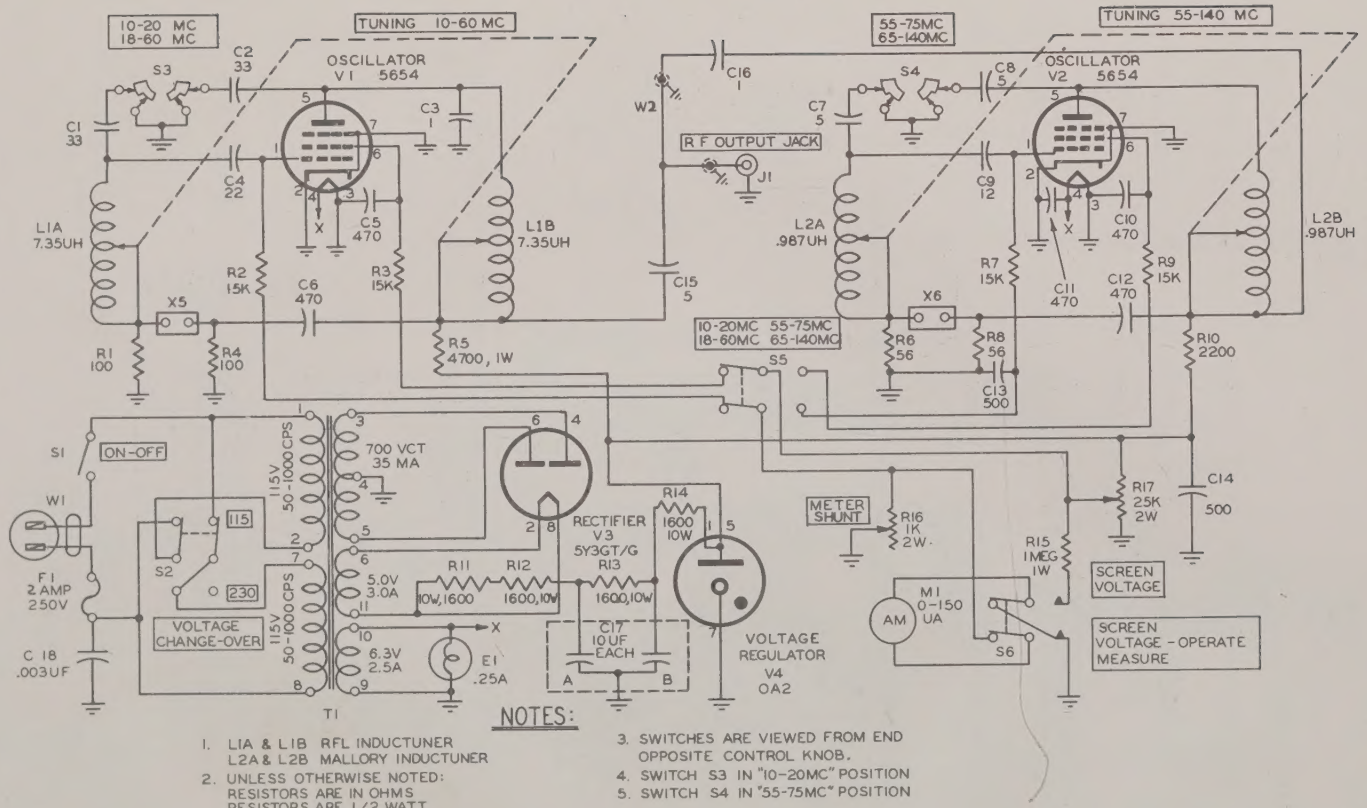



*Figure 17. Wiring Diagram of Crystal Impedance Meter Model 531*




NOTES:

1. L1A & L1B RFL INDUCTUNER
   L2A & L2B MALLORY INDUCTUNER
2. UNLESS OTHERWISE NOTED:
   RESISTORS ARE IN OHMS
   RESISTORS ARE 1/2 WATT
   CAPACITORS ARE IN UUF
3. SWITCHES ARE VIEWED FROM END OPPOSITE CONTROL KNOB.
4. SWITCH S3 IN "10-20MC" POSITION
5. SWITCH S4 IN "55-75MC" POSITION

*Figure 18. Schematic Diagram of Crystal Impedance Meter Model 531*